FTD-HT-23-108-72

FOREIGN TECHNOLOGY DIVISION

CONSTRUCTION OF "COSMOS" SATELLITES

by

Yu. I. Zaytsev

85

FTD-HT- 23-108-72

EDITED TRANSLATION

FTD-HT-23-108-72

CONSTRUCTION OF "COSMOS" SATELLITES

By: Yu. I. Zaytsev

English pages: 80

Source: Sputniki Kosmos (Cosmos Satellites), Izd-vo Znaniye, 1970, pp. 1-63.

Requester: FTD/PDSX

Translated by: Robert A. Potts and Bernard L. Tauber

Approved for public release; distribution unlimited.

THIS TRANSLATION IS A RENDITION OF THE ORIGINAL FOREIGN TEXT WITHOUT ANY ANALYTICAL OR EDITORIAL COMMENT. STATEMENTS OR THEORIES ADVOCATED OR IMPLIED ARE THOSE OF THE SOURCE AND DO NOT NECESSARILY REFLECT THE POSITION OR OPINION OF THE FOREIGN TECHNOLOGY DIVISION.	PREPARED BY: TRANSLATION DIVISION FOREIGN TECHNOLOGY DIVISION WP-AFB, OHIO.

UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author)	2a. REPORT SECURITY CLASSIFICATION
Foreign Technology Division Air Force Systems Command U. S. Air Force	UNCLASSIFIED
	2b. GROUP

3. REPORT TITLE

CONSTRUCTION OF "COSMOS" SATELLITES

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Translation

5. AUTHOR(S) (First name, middle initial, last name)

Yu. I. Zaytsev

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
1970	80	

8a. CONTRACT OR GRANT NO.	9a. ORIGINATOR'S REPORT NUMBER(S)
b. PROJECT NO.	FTD-HT-23-~~0~~108-72
c.	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)
d. DIA T70-16-04 & T70-16-01	

10. DISTRIBUTION STATEMENT

Approved for public release; distribution unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	Foreign Technology Division Wright-Patterson AFB, Ohio

13. ABSTRACT

The design and employment of Soviet satellites of the "Cosmos" series is discussed. A brief discussion of the overall "Cosmos" program is discussed followed by a more detailed discussion of its specific sub programs: investigation of the lower atmosphere, investigations of the structure and variations of the upper atmosphere, investigations of the ionosphere, the study of corpuscular radiation, investigation of radiation at low altitudes, investigation of the sun's shortwave radiation, investigation of meteoric matter, measurement of the earth's magnetic field, telescopes in space, cosmic rays, and other technical experiments.

DD FORM 1 NOV 65 1473

UNCLASSIFIED

Security Classification

14 KEY WORDS	LINK A ROLE	LINK A WT	LINK B ROLE	LINK B WT	LINK C ROLE	LINK C WT
Artificial Earth Satellite						
Cosmic Ray						
Earth Magnetic Field						
Atmospheric Radiation						

U. S. BOARD ON GEOGRAPHIC NAMES TRANSLITERATION SYSTEM

Block	Italic	Transliteration	Block	Italic	Transliteration
А а	*А а*	A, a	Р р	*Р р*	R, r
Б б	*Б б*	B, b	С с	*С с*	S, s
В в	*В в*	V, v	Т т	*Т т*	T, t
Г г	*Г г*	G, g	У у	*У у*	U, u
Д д	*Д д*	D, d	Ф ф	*Ф ф*	F, f
Е е	*Е е*	Ye, ye; E, e*	Х х	*Х х*	Kh, kh
Ж ж	*Ж ж*	Zh, zh	Ц ц	*Ц ц*	Ts, ts
З з	*З з*	Z, z	Ч ч	*Ч ч*	Ch, ch
И и	*И и*	I, i	Ш ш	*Ш ш*	Sh, sh
Й й	*Й й*	Y, y	Щ щ	*Щ щ*	Shch, shch
К к	*К к*	K, k	Ъ ъ	*Ъ ъ*	"
Л л	*Л л*	L, l	Ы ы	*Ы ы*	Y, y
М м	*М м*	M, m	Ь ь	*Ь ь*	'
Н н	*Н н*	N, n	Э э	*Э э*	E, e
О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

* ye initially, after vowels, and after ъ, ь; e elsewhere. When written as ё in Russian, transliterate as yё or ё. The use of diacritical marks is preferred, but such marks may be omitted when expediency dictates.

The artificial earth satellite "Cosmos-1" began orbital flight 16 March 1962. After 8 years, in April 1970, information was published in the press about the successive launching of eight satellites of this series at once - "Cosmos-336 - 343".

The "Cosmos" satellites achieved a strong place in the arsenal of means of investigating outer space conducted in the Soviet Union. The quantity of these vehicles is increasing every year. During 1962-1963 there were launched 24 "Cosmos" satellites, and in 1964 alone 27; in 1965 - 52. In 1968 a record was achieved: 64 "Cosmos" satellites (from 199 to 262 inclusively) accomplished orbital flight. The flight routes of the satellites became diverse. The first "Cosmos" satellites flew at altitude up to 1600 km above the earth's surface, and now they reach altitudes up to several tens of thousands of kilometers. The launching of satellites into near-polar orbits permits studying the new, earlier unattainable regions of space.

In separate experiments several "Cosmos" satellites (up to eight) were injected into orbits with one launch vehicle.

Fig. 1. "Cosmos" launch vehicle.

CONSTRUCTION OF "COSMOS" SATELLITES.

Once the space vehicles were distinguished by their individuality. It is sufficient to look at the first, second or third artificial satellites, in order to get an idea of the uniqueness of each of them. The further development of space research put forward the problem of the transition from the manufacture of individual constructions to the mass production of unified vehicles of the same type. The advantage of unification is obvious. First of all it is possible to organize series production of both assembly elements and the satellites themselves. Thereby the cost of the vehicles is considerably reduced and, consequently, the conducting of space research. The problem of series production stood before the creaters of the "Cosmos" series satellites.

However, the construction of the satellites primarily depends on what scientific equipment should be placed on board. For the study in outer space of various phenomena of interest to physicists, chemists, biologists, there are necessary various instruments, energy sources and others. Depending upon the missions assigned, the satellite either returns to earth, or after completion of the experiment burns up in the dense layers of the atmosphere. Sometimes it is necessary to equip the satellite with an orientation system. The electric energy sources also depend on the requirements imposed on the satellite. In one case this will be chemical storage batteries if the time of conducting the investigations is brief, in another - solar batteries, able to feed current to scientific equipment and

airborne systems many months and even years.

Thus, the development of a universal space vehicle satisfying all requirements of space research is practically unfeasible. It will be very cumbersome and heavy. But it proved to be possible to create several modifications of a unified satellite, making it possible to conduct some scientific research works that are uniform or close in character. With the transition from one modification to another maximum continuity of the construction is maintained; the systems being used do not depend on the concrete task of the experiment. Unification primarily concerns the body of the vehicle. It consists of three standard units - a cylinder and two half spheres. Each unit represents one compartment. In one - the scientific equipment, in another - service systems: radio monitoring of the orbit, telemetry, command radio link, in the third compartment - power supply source.

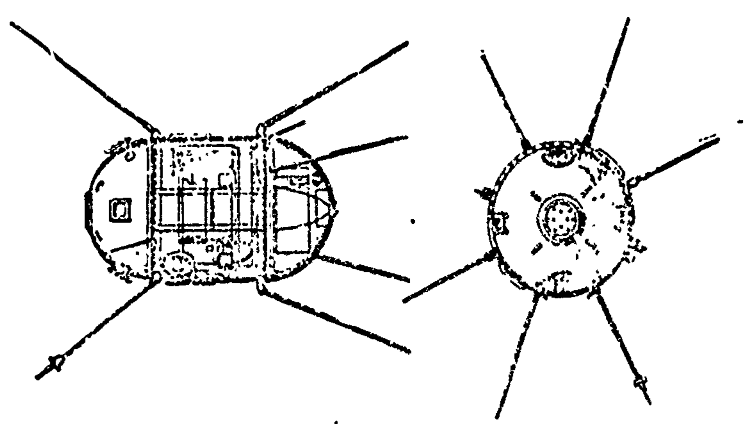

Fig. 2. Modification of unified satellite with chemical current source.

On the external surface of the body are provided special brackets and flanges for attaching instruments and senors of scientific equipment. They can be installed directly on the body

or with the aid of adapters. The electrical connection of these instruments with the power supply source and equipment, located inside the housing, is accomplished through sealed plug and socket connectors.

The life of the space vehicle is determined to a considerable degree by its heat conditions. Most of the elements of the space equipment are designed for temperatures from -60 to +50 degrees C. Still narrower is the temperature range of "life" of the electronic equipment. It operates best at room temperature.

During motion of the space vehicle in orbit it is heated by direct and reflected solar rays, and also due to the energy of the earth's radiation itself and heat being released during operation of the airborne equipment. The heating of the satellite from solar radiation is determined by the time of its stay on the illuminated side of earth. For space vehicles launched into low orbits, 65-70% of their orbital period is on the illuminated side. The orbit can occupy such a position at which the satellite is continuously illuminated by the Sun several days.

Along with absorption of heat by the space vehicle there occurs heat emission from its external surface as a result of radiation. The temperature inside the satellite will be determined by the equilibrium of absorbable and radiated radiation. For maintaining the equilibrium in the necessary limits there is the thermal control system of the satellite.

The thermal control systems of the space vehicles can be of two types - passive and active. The first one is simpler. The external surface of the satellite is specially treated for giving it the necessary values of coefficients of absorption of solar

radiation and self-radiation. For the removal of heat released during operation of the airborne equipment to the shell of the body the satellite is filled with gas heat-transfer agent. Inasmuch as in the state of weightlessness free convection is impossible, we resort to forced circulation of gas with the aid of fans.

The disadvantage of such a system involves the fact that for its calculation it is necessary to precisely know all the thermal characteristics in orbit, and consequently, to precisely inject the satellite into the designed trajectory and to precisely observe the time of launch. Even small deviations can lead to the danger of overheating or, conversely, to overcooling of the space vehicle Futhermore, with the passage of time the covering of the body is changed.

On "Cosmos" satellites we applied the active system of thermal control of the "climate" inside the satellite. For this radiators and the shutters covering them were installed on it. The radiator serves the bottom half-shell of the housing, on the surface of which in the form of sectors is applied a ceramic coating with raised emissivity. The shutters are a movable screen; freely moving over the surface of the radiator, they regulate its emissivity. The system is controlled automatically by signals from temperature pickups located inside the housing of the satellite. The prescribed temperature is ensured exceptionally accurately.

* * *

On the first earth satellites the equipment required relatively low power of electrical energy and its operating time was brief. Therefore ordinary batteries were successfully applied. Their main advantages: high reliability and excellent operational qualities.

The substantial disadvantage - large weight with small energy capacity. However, with small power requirement and service life up to one month the batteries as autonomous current sources are more economical than solar batteries. At the same time the storage batteries permit carrying out scientific measurements at high vacuum purity. Solar batteries in space under the action of vacuum and radiation start to erode and "bubble up". Around the satellite is created a layer of microatmosphere. Consequently, it is impossible to use solar batteries, for example, during the study of the physicochemical composition and the density of the upper layers of the atmosphere. In these cases there is appliec a modification of a unified satellite with chemical sources of current (first modification).

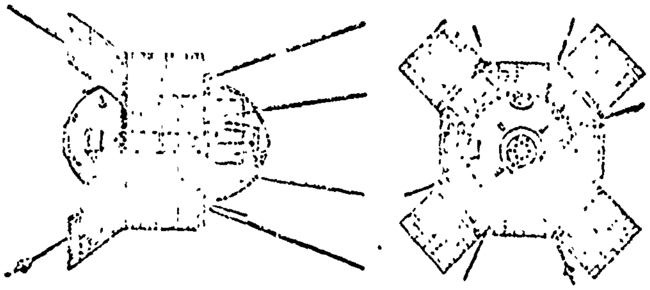

Fig. 3. Modification of unified satellite with solar batteries.

The transition from the first modification to the second was accomplished by replacement of the unit of chemical sources of current by a power-supply system with solar batteries, which are installed on the body of the satellite. Such a battery is a regular octahedral prism with four notches for scientific equipment

and opening panels. Each cell of the solar battery consists of two layers of silicon. The internal layer - pure single-crystal silicon. On the outside it is coated with a very thin layer of silicon "contaminated" with impurity (outside layer). With the irradiation of such a "wafer" by solar rays between the layers there appears a flow of electrons and a potential difference is formed.

Solar batteries do not produce electrical energy in shade; therefore they are applied in conjunction with storage batteries. The latter serve not only as accumulators, but also dampers of possible fluctuations in the energy consumption.

In the first two modifications of the satellite the possibility of the installation of additional systems is provided for. For example, a system for slowing the spinning of the satellite (so-called system of stabilization) can be installed. Usually with separation from the last stage of the launch vehicle the satellite acquires random spinning with period up to tens of seconds. In flight the satellite is affected by various disturbing forces, which tend to additionally twist it. These include the rotation of various motors located inside the vehicle the unsymmetric action of the earth's atmosphere, if the satellite flies at low height. Tumbling of the satellite hampers the conducting of scientific measurements. In particular, because of the insufficient time of exposure it would not be possible to observe objects with low radiation strength. It is necessary to slow the spinning of the satellite. For this purpose a special magnetic system of stabilization is used on "Cosmos".

* * *

During motion of the satellite in orbit the designed trajectory is maintained only by the center of mass (we could say center of

gravity, but in power-off flight there is no gravity - the satellite is weightless). The vehicle itself under the action of various disturbances can change its position relative to some definite coordinate system connected with the center of mass. It would seem that this is, in fact, even good if the body of the satellite is stationary; then its parts, turned to the Sun, can be heated (with little contact with the body) to 100 degrees C. But at the same time the parts located in the shade are cooled to -150 degrees C and lower. It is difficult for the thermal control system to handle such temperature drops.

However for the solution of most practical and many scientific problems it is necessary to give the space vehicles a certain position in space, i.e., they should be oriented with respect to the surrounding celestial bodies - Sun, Earth or stars, with the required precision for a long time. For example, for the study of processes connected with the Sun it is required that one of the axes of the satellite, and namely the appropriate direction of setting of the sensing elements of scientific equipment, be strictly oriented to the Sun. For conducting such investigations there is the third modification of the "Cosmos" satellite.

In order to accomplish orientation it is necessary to apply forces to the space vehicle, causing its body to turn around the center of mass. During orientation to the Sun it is possible to use, for example, miniature reaction engines for which the gas jets are directed in different directions with respect to the axes of the satellite, or to a system of inertial masses (flywheels) revolving inside the satellite. The second method, proposed even by K. E. Tsiolkovskiy, is based on one of the classical laws of mechanics

- law of conservation of the moment of momentum. The flywheels "take in" the angular velocity, which the satellite body had after separation from the launch vehicle, and then force it to turn to the necessary angle, i.e., orient in space.

The substantial disadvantage of the orientation system using reaction engines is the limited service life, since its operation is coupled with the flow rate of some working medium, the reserves of which are usually small on board. The flywheels rotate the electric engines which consume electrical energy being produced, for example, by solar batteries.

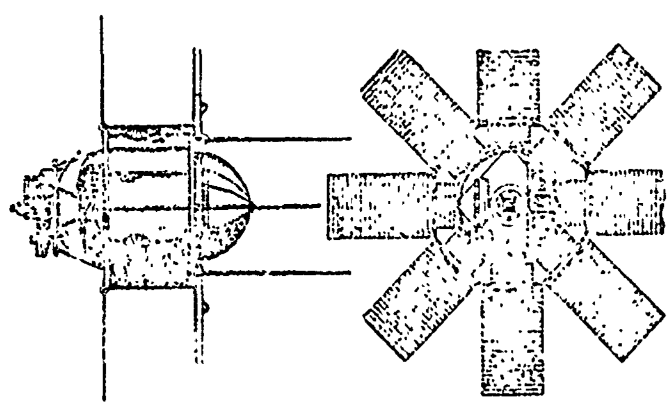

Fig. 4. "Solar" satellite (third modification).

The speed of rotation acquired by the flywheels is proportional to the external disturbing moment. Their rotation in this case is directed toward the direction of motion of the body of the satellite. The flywheels will continue to rotate with ever increasing angular velocities after the movement of the satellite around its axis is ceased. The system normally operates only if the external disturbing moments periodically change their sign.

The external moment of one sign, i.e., acting constantly in one direction, even if it is small, can make the system inefficient. Therefore it is necessary from time to time to liquidate the moment of momentum accumulated on the flywheels.

The most expedient is the application of combined systems in which the engines-flywheels serve for precise orientation and compensation of periodic moments, and the reaction engines - for removal of the accumulated kinetic moment of flywheels and compensation of constantly acting moments. Just such a combined system is used on the third modification of the "Cosmos" satellite. It provides high accuracy of orientation with a long time of active existence of the satellite.

The system operates in a certain sequence. First of all with the aid of a gas-reaction system the random angular velocities, acquired by the satellite during separation from the launch vehicle, are decreased. After cessation of the random rotation of the satellite the orientation system begins the search for the Sun. For this there are used the engines-flywheels controlled by signals of the Sun pickup located on the forward half-sphere of the body. When the misalignment angles and the angular velocities of rotation are decreased to the prescribed limit, "steady state" sets in, i.e., holding of the oriented axis in the prescribed direction with certain accuracy.

Thus, the satellite will always be turned with the forward half-sphere to the Sun. In this case special requirements are imposed on the temperature conditions of operation of the airborne equipment. To avoid its overheating the body of the satellite is covered with special vacuum-shield heat insulation. The panels

of the solar batteries are arranged so that they are maximally illuminated by the Sun.

* * *

The geophysical instruments aboard the satellite require orientation of the satellite to certain sections of the earth's surface. The same orientation to earth is necessary during investigation of the radiation conditions of the atmosphere and for other experiments. In this case there is used the "Cosmos" satellite modification with aerodynamic orientation system.

For satellites with a long time of active existence it is more preferable to use passive orientation systems, i.e., those for which an airborne energy source is not needed. These include also systems where an insignificant amount of energy is used only for maintaining constant angular velocity of rotation of gyroscope rotors, for compensation of losses due to friction or overcoming the dead zone of flywheels, rotating at constant speed. It is possible, for example, to orient the satellite relative to local vertical using the properties of the earth's gravitational field. For orientation to the Sun it is proposed to use the effect of light pressure of solar rays, and during flight at low altitudes along a circular orbit - the stabilizing action of air drag of the atmosphere. Very promising for stabilization of the space vehicle is the application of the controllable interaction of the body and the electrical and magnetic fields connected with it with external force fields.

An essential disadvantage of passive systems - comparatively small value of control moments. For their intensification special devices - stabilizers are applied.

The aerogyroscopic orientation system of the fourth modification of the unified satellite pertains to the passive systems. The

aerostabilizer, which is attached to the body on extensible rods, with respect to the satellite plays as if the role of the feathers of an arrow. Under the action of air drag forces there appear restoring moments with respect to pitching and yawing which tend to combine the longitudinal axis of the satellite with the velocity vector of the incoming air. However, only aerodynamic moments alone do not create damped oscillations; the decrease of disturbed motions of the satellite is accomplished by a gyrodamper.

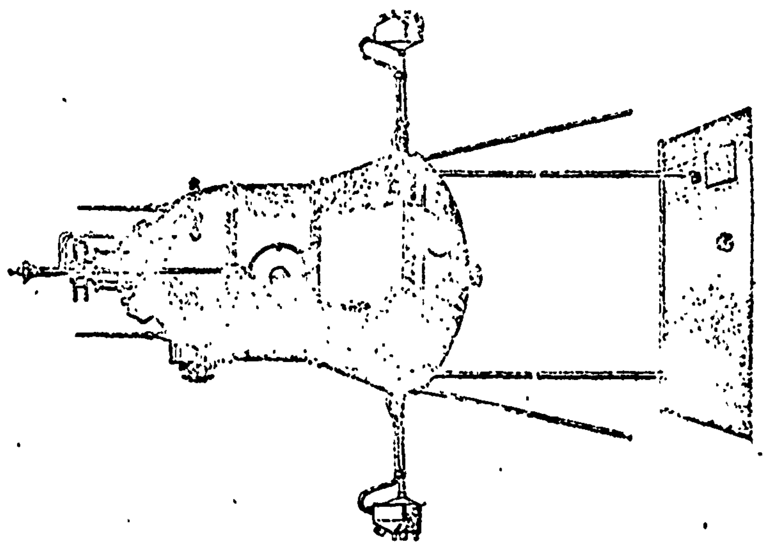

Fig. 5. Unified satellite with aerogyroscopic orientation system (fourth modification).

The disturbances appearing with separation of the satellite from the launch vehicle, are reduced with the aid of brief acting gas-reaction system of stabilization located on its forward half-sphere.

The development of a satellite being stabilized as an arrow with the aid of aerodynamic forces - a complex technical problem.

It is known that the upper layers of the atmosphere are very rarefied. Thus, at altitude 250-300 km the density of the atmosphere is 10^{-14} g/cm^3. The force of air drag caused by the interaction of the satellite with the atmosphere will be measured only by tenths of a gram (0.1-0.5 g). Furthermore, the state of the atmosphere depends on many factors, the main being solar activity. Constantly being blown by solar corpuscular flows, the atmosphere as if breathes, sometimes contracting, sometimes, conversely, expanding. At an altitude of 300 km its density can be changed by more than 10 times. These properties of the atmosphere impose exceptionally high requirments on the precision of orbital injection of the satellite. Even with small deviations from the designed trajectory it is either not stabilized or the time of its active existence will be insufficient for carrying out the planned investigations.

* * *

The satellite of the "Cosmos" series, the scientific instruments and objects of experiment of which are returned to earth, outwardly substantially differs from the first four modifications. It consists of three standard units: autonomous module-capsule, instrument compartment, braking rocket. The accommodation of various scientific equipment on board is not connected with the necessity of change of the geometric shape of the capsule, the nonrecoverable part of the satellite, service systems, electrical circuit and control and descent schemes.

The motion of the artificial satellite relative to the earth proceeds at a velocity equal to or somewhat differing from the circular velocity. During descent this velocity should be reduced and at the moment of landing should be equal to zero. In practice it is possible to apply two methods of braking the space vehicle

during descent, differing in principle: by means of the use of reactive force, or aerodynamic forces appearing during motion of the satellite in the atmosphere.

For accomplishment of the first method of descent the vehicle or its recoverable part should be equipped with a power plant and a fuel supply. During descent with the use of aerodynamic braking the space vehicle is equipped with special devices, increasing its midsection several tens and even hundreds of times - the greatest in the cross-sectional area, and consequently, the resistance to motion in the atmosphere. Such a device can be, for example, a parachute, opening at a certain stage of descent. The ratio of weight of the payload to the overall weight of the space vehicle with the use of aerodynamic forces for descent is more favorable than in the case of the application of reactive forces. The weight of the heat shield of the lifting surfaces and other elements of the vehicle prove to be less than the weight of fuel necessary for braking with the reaction engine. That is why for descent of the capsule of a unified satellite there is selected the second method, i.e., the use of aerodynamic forces. The decrease of orbital velocity is provided by the braking rocket. Before its ignition the satellite is oriented in space in the prescribed manner.

INTERNAL SERVICE EQUIPMENT

The radiotelemetric system for transmission to the earth of data of measurements and also information about the operation of instruments and scientific equipment - one of the many radio systems on board the satellite. Without it the scientists could

not find out anything. This system "connects" the sensors of the scientific equipment with the ground data-processing center.

The constructions of sensors and the principles of their operation are diverse. The type of each sensor is determined by the character of the physical value for the measurement of which it serves. Some sensors should be located outside the sealed body and have direct contact with the surrounding space, for example sensors for investigation of the physicochemical parameters of the upper atmosphere. Others can be placed inside the vehicle. The output signal of the measuring element usually cannot be used for direct transmission to earth. First it proceeds to an amplifier-converter, where it acquires the form corresponding to the set standard.

The radiotelemetric system provides simultaneous transmission of a large quantity of measured values. With the aid of special commutative device to the input of the system there is performed successive connection of scientific instruments and sensors. The frequency of connection can be from several times to several hundreds of times per second. At the ground receiving stations there are also commutative devices, which operate in step with the commutator on board. This permits separately recording the telemetric signals transmitted on one common channel.

The scientific equipment of the satellite in accordance with a program takes measurements at many points of the orbit. The radiotelemetric system can transmit information only in zones of direct radio visual range with the ground stations. When there is no communication of the satellite with the measuring points a data-storage device is used. where there is stored scientific

information and data about the operation of internal systems for one or several passes in orbit.

During communication sessions along with the transmission of accumulated information there is conducted direct telemetric transmission of many parameters recorded by the scientific equipment. Data-storage device data are reproduced at very high speed, and the ground stations are rapidly freed for communication with other space vehicles.

During the flights of space vehicles the measurement of characteristics of motion of the satellite is very important - coordinates and velocity vector components at different moments of time. For this in the composition of the complex of service systems there is introduced equipment for remote checking of the orbit by radio. On the basis of the data obtained from it there are determined the parameters of the orbit of the satellite and its position is predicted, necessary for the output of target indications to the ground observation points.

The remote radio checking system consists of the radio transmitter, operating under conditions of continuous radiation or prolonged impulses radiating sufficiently. The ground measuring points are equipped with sensitive receivers and devices for measuring the frequency of the signals received. The principle of operation of the system involves the fact that with relative approach to the ground point or withdrawal of the satellite the frequency of the signal recorded by the receiver differs from the frequency of the signal emitted by the transmitter by a certain value proportional to the velocity of approach or withdrawal. During the approach the frequency of the received signal is greater, and during withdrawal

is less than the frequency of the emitted signal. The closer the satellite approaches the ground station, the faster the frequency of the received signal is changed from maximum to minimum. By recording the frequency of the received radio signal, it is possible with great accuracy to establish the moment of passage of the satellite at minimum distance from the ground point. By knowing the moment of passage of the satellite at minimum distance with respect to several ground points, we compute the main parameters of its orbit.

The operation of the equipment of the satellite is controlled by two methods: the first - by commands transmitted to the satellite from ground points by special command radio link; and the second - autonomously, with the aid of a timer-programer.

The first method is more flexible. Although the number of commands which can be transmitted to the satellite from earth is limited, they are distributed so that when necessary it is possible to provide operational interference to the work of the internal systems and to change their conditions.

For conducting scientific experiment information about the angular position of the satellite in space at each moment of time can be necessary. For this on board the satellite is installed an induction system, including various sensing elements - solar sensor, magnetometer, etc. Their readings are recorded in the data-storage device simultaneously with the results of measurements of scientific equipment and then transmitted to earth by the radiotelemetric system.

"COSMOS" SERIES METEOROLOGICAL SATELLITE.

The creation of a unified space vehicle, of course, does not exclude the necessity of development of satellites for conducting special investigations. These primarily pertain to various technical experiments in space such as, for example, automatic docking in orbit, testing of separate units of space vehicles, etc.

For the collection of meteorological information and its transmission to earth in our country there was created a special meteorological satellite "Meteor", the systems of which were worked out on satellites of the "Cosmos" series.

The body of the meteorological satellite is a sealed container, divided into two compartments. In the upper compartment are located the main service systems, in the lower - the scientific equipment. The two panels of solar batteries, consisting of many thousands of photocells, provide the satellite with electrical energy. At the moment of launch and on the powered phase the solar batteries are in folded state and are opened after separation of the satellite from the launch vehicle. The self-contained tracking system provides constant orientation of the plane of batteries perpendicular to the direction of solar rays. As sensing elements of the direction to the Sun special photocells are applied, reacting only to a certain part of the spectrum of solar radiation. For protection against overcharging of the storage batteries or inadmissible lowering of voltage there is an automatic power supply control system.

For most internal instruments of the satellite there is used alternating current in the frequency range from tens to hundreds

of Hertz. The direct current of the storage battery is converted into alternating by static semiconducting converters which are simultaneously automatic regulators of voltage and frequency of alternating current. These converters also provide synchronism of operation of electric motors installed in the various mechanisms of the satellite.

During flight the satellite is strictly oriented to earth. One of its axes is directed to the center of earth, a second - along the trajectory and third - perpendicular to the orbital plane. For determination of the direction to earth there is used an instrument reacting to its thermal radiation, a so-called infrared vertical. Electric motors-flywheels serve as the actuators of the orientation system.

Strict orientation of the satellite permitted using a scanning device which keeps track of the processes in the earth's atmosphere, scanning it all the time in the transverse plane from right to left and from left to right.

Besides the orientation and power supply systems, the composition of internal equipment of the meteorological satellite includes a radiotelemetric system with data-storage device, satellite radio observation system and system of measurement of the parameters of motion of the satellite, thermal control system, central timing system for linking the results of measurement with the terrain, control system, consisting of an internal automatic device and a command radio link.

SATELLITE TESTING

The process of manufacture and development of the satellite consists of several cycles or stages. First we prepare a full-scale mockup of it. On it there is checked the adaptability of the parts and units for industrial production, there is determined the necessary rigidity of structural elements, for example, panels of solar batteries, instrument mounts. Incidently there is solved the problem of how to best arrange the internal equipment, to best achieve convenience of monitoring all the systems when testing. At this stage, called three-dimensional mockup, the length of the cable network and the configuration are established, the conditions of loading the space vehicle into a container and its unloading are determined, and also the technological equipment for working with it at the plant and the space center is developed.

Space - an unusual medium with respect to earth concepts. In space there are deep vacuum, weightlessness, severe temperature fluctuations, and various types of radiations.

Under the action of space vacuum from the surface of the body material will be continously volatized, erosion will occur. As a result the radiation characteristics of the space vehicle are substantially impaired. The heat transfer between its parts is hindered, which in the final analysis affects the overall heat balance. In space vacuum the friction and wear of materials are substantially increased. Phenomena of so-called "cold welding" can appear. It is necessary to know beforehand how the space vehicle behaves in flight. Therefore it is necessary to create conditions on earth, similar to conditions in space, and to conduct tests of the vehicle in them. On the earth there is simulated such specific actions as vibrations and mechanical overloads on the powered flight

phase or the thermal conditions of the descent capsule during reentry. On special stands we check the strength of the construction of the space vehicle, maximum allowable longitudinal and transverse loads on the body and instrument mounts, the efficiency of separate elements during vibrations. In vacuum installations under conditions maximally approaching real there are developed mechanisms for unfolding the antennas and panels of solar batteries, construction of locks, catches and connecting mechanisms. When checking the operation of the thermal control system the heat-sensitive elements are heated and cooled to limiting temperatures and their action is monitored. In a heat chamber there is determined the deformation of instrument mounts under the action of possible temperature drops between the compartments of the object.

In accordance with the technical mission the space vehicle should operate for a definite and rather prolonged time necessary for carrying out the entire experimental program. The capability of the equipment to function normally for this entire period is revealed by the durability tests. In order to be insured against chance, they last considerably longer than the time established by the technical specification. Only those instruments and units having undergone the entire cycle of experimental development without any criticisms are allowed for further operations.

The next stage - complex electrical tests of the equipment. Their purpose - to check the interaction of instruments and the internal electrical power and control systems. The separate units and components of the space vehicle are placed on spaced supports and technological carriages, which provide free access to the equip-

ment when determining the troubles or replacing the instruments. The units and components are connected together with special cables - extenders. The power supply is carried out from ground current sources.

Complex tests on the investigated object are the most important part of plant tests. When conducting them there is maintained strict sequence of operations which reflect the operation of instruments and the interaction of its separate units at the moment of launch, on the powered phase, during separation from the launch vehicle and in orbital flight.

The programmer issues commands in series to varicus components of the equipment, units of the control system. There is also checked the use of commands transmitted by the radio link of the launch vehicle, the cut-in of systems of the space vehicle during actuation of the sensing elements of separation. Then the electronic equipment as if "plays back" the entire flight, the behavior of each instrument in space. There is determined the sensitivity of the systems to commands transmitted by the radio link from earth. On the screens of the ground station of telemetric measurements the initial levels of the parameters of the equipment are monitored, the quality of operation of the automatic equipment of the data-storage device is evaluated, the output powers of the transmitters and the time of cycles of the programmers are determined; the time of actuation of the relay of maximum and minimum current and the issue of the command for shutting off the load with lowering of voltage of the power supply source is monitored. And this goes on until the entire space vehicle is tested in action.

After the completion of tests the equipment heads for the

assembly shop.

The division of the construction of the satellite into separate compartments, components and units permits applying multiple-series sequence of operations during assembly. As a result there is provided a continuous process of assembly and a wide front of operations.

In the process of assembly special attention is paid to the check of the airtightness of the body. For this it is filled with some gas possessing high fluidity. First there are determined the possible local leakages, and then the total inleakage of gas in an altitude chamber with deep vacuum.

Simultaneously with the check of the body for airtightness there proceeds assembly of the mounting frames with scientific and service equipment. Part of the instruments are located on the outside surface of the space vehicle. These are the most sensitive elements of the scientific equipment, sensing devices of the orientation system, etc. The precision of installation is achieved by thorough preparation of the compartments and the high quality of assembly operations.

Complex tests of the internal equipment on the assembled object complete the cycle of electrical tests at the plant. Tests basically repeat the preceding program. At the same time the method of conducting them considers the impossibility of connecting instrumentation to the internal instruments. The operation of the systems is evaluated by the data of telemetry.

Upon completion of electrical tests the current sources are removed from the satellite, and then together with the solar batteries it is placed in a special container in which it is delivered to the space center.

At the technical position of the space center after unloading from the container the space vehicle is placed on a technological carriage and its external inspection and check of the assembling units and parts are performed. The ground cable network is unrolled and connected and the monitoring and testing equipment for checking the control connections is hooked up. Its normal functioning is checked. Then on the space vehicle is installed the flight battery and then the vehicle is placed on the tilting mechanism for its coupling with the launch vehicle and for conducting the final operations.

Upon the completion of these operations the space vehicle, coupled with the rocket and covered with a fairing, is transported to the launching pad. The volume and sequence of the preceding operations are strictly regulated in time. The program of tests of the space vehicle on the launching position is usually reduced to minimum and includes basically a check of the initial state of the internal systems and preparation of the vehicle for operation. The systems are actuated immediately before launch. The transfer of power supply from ground sources to internal is concluded by preparation of the space vehicle for launching.

THE PROGRAM OF "COSMOS" SATELLITES

The successful flights of the first artificial earth satellites in the world, launched according to the program of the International Geophysical Year, gave quite extensive information about the parameters of the upper atmosphere and the physical processes proceeding there. The first unmanned space probes permitted expanding

the observations to the far environs of the earth, interplanetary space and the Moon. However, many results needed checking and confirmation. Futhermore, the investigations were conducted in the period of maximum solar activity. For the study of the relationship of parameters of the upper atmosphere and interplanetary medium to the solar activity it was necessary to accumulate a rather large quantity of experimental material in the period of its drop and minimum. There also appeared the necessity of specialized and complex experiments directed toward the preparation and solution of more complex problems of man's penetration into space.

These tasks were placed on the numerous "Cosmos" series satellites. Thus, the accomplishment of a new expanded program of study of the upper layers of the atmosphere and near space with the aid of "Cosmos" series satellites - logically the basis of the continuation and development of the previous stage of investigations.

The scientific program of the "Cosmos" series satellites provides for:

the study of the distribution and formation of cloud systems in the earth's atmosphere;

the study of the upper layers of the atmosphere;

the study of the concentration of charged particles in the ionosphere for the purpose of investigating the propagation of radio waves;

the study of corpuscular flows and particles of low energies;

the study of the energy composition of the earth's radiation belts with evaluation of the radiation hazard during prolonged space flights;

the study of the earth's magnetic field;

the study of shortwave radiation of the sun and other cosmic bodies;

the study of meteor matter in the earth's environs or its action on the structural elements of the space objects.

The "Cosmos" satellites, besides the numerous scientific tasks, permitted solving a number of technical problems connected, for example, with the return of the cabin of the vehicle to the earth's atmosphere, development of the orientation system, touchdown in the prescribed region, protection of the ship from radiation, the study of the degree of reliability of the separate units of the life-support systems and others.

Since "Cosmos-1" began its orbital flight, a number of important scientific results have been obtained. Some of them will be discussed. These results are of interest by themselves and demonstrate the successes in the development of space and rocket technology achieved in recent years.

INVESTIGATIONS OF THE LOWER ATMOSPHERE

With the aid of "Cosmos" series satellites there is carried out a program of investigation of the structure of the earth's atmosphere and processes in its lower layers having enormous value for human system activity. In the lower layers of the atmosphere are developed the powerful processes which form the weather and in the final analysis form the climate on earth.

The physical characteristics determining the state of the lower layers of the atmosphere - pressure, temperature, moisture and others - cannot be directly measured from satellites flying

at altitudes of 200 km and higher. Atmospheric parameters are determined by indirect methods. Directly on the satellites there is recorded only the earth's radiation in various sections of the spectrum of electromagnetic waves in the ultraviolet, visible and infrared ranges, and also thermal and radiowave radiation of the earth.

With the aid of television cameras, actinometric and other equipment installed on the satellites, it is possible to trace the distribution of the cloud cover over the entire globe, determine the occurrence boundaries and dynamics of the snow cover and ice fields, measure the flows of radiation arriving in the earth's atmosphere from the Sun and leaving conversely into space.

The satellites give the picture of the distribution of cloudiness over vast spaces of the earth's surface with such completeness and objectivity, which cannot be obtained with the aid of ordinary ground facilities. It is possible to more thoroughly study the cloud system of cyclones, atmospheric fronts of various air masses, change of cloudiness in the process of evolution and and the movement of these objects. Especially important are data about cloudiness obtained from satellites for those regions of the globe where ordinary meteorological observations are very rare or completely absent.

The first experiment of television tracking of clouds was conducted from the "Cosmos-4" satellite, and then special meteorological satellites of the "Cosmos" series appeared. The equipment of these satellites permits obtaining an image of the cloudiness, snow cover, ice fields on the illuminated and the dark sides of the earth, permits measuring the flows of radiation, reflected and

radiated by the "earth-atmosphere" system. For the observation of cloudiness on the illuminated side of the earth, television equipment is used. Two cameras provide frame photography of the earth's surface along the flight path of the satellite. The television equipment is turned on automatically at angles of elevation of the Sun above the horizon over 5 degrees.

In the process of flight of the satellite the illumination of the earth is substantially changed. For this in order to obtain high-quality photographs, the exposure is regulated with the aid of an automatic device which measures the illumination of the earth and sets the needed stop of the optical system. From an altitude on the order of 625 km the television cameras transmit photographs of the earth's surface along the flight path of the satellite with pickup width around a thousand kilometers. The high resolution of photographing permits sharply determining the shape of the cloudiness and conducting detailed analysis of atmospheric processes occurring in this region.

Observations of the cloudiness on the dark side of earth are accomplished with the aid of infrared equipment which measures the departing radiation of the earth's surface and clouds. The amount of departing thermal energy is determined by the temperature of the radiating surface, and since the clouds are always colder than the earth's surface, their radiation is less intense.

Photographs of the cloud systems obtained with the aid of the infrared device are less detailed than television, but are sufficiently detailed for analysis of large atmospheric formations (cyclones, typhoons, atmospheric fronts) with characteristic cloud systems, the size of which is determined by hundreds and thousands of kilometers.

The information obtained in this way about the state of the cloud cover and certain atmospheric processes connected with it, which appear in the form of contrasts of radiation of the earth's surface and clouds in some interval of the spectrum, is used by weather forecasters of weather service centers. On the basis of this information the analyses of weather maps and weather forecasts for several days in advance are refined.

The results of investigations of the atmosphere obtained with the aid of meteorological satellites carry a practically qualitative character. The quantitative characteristics of the state of the atmosphere obtained with the aid of equipment of the satellites as yet have limited application. The accuracy of these measurements is insufficient, which serves as an obstacle for the reliable solution of problems of satellite meteorology. Even small errors of measurements can be the cause of inadmissibly large errors of determination of the sought atmospheric parameters inasmuch as they lead to the solution of so called inverse problems, uncorrected in the mathematical sense.

At present the most important and actually fulfilled is the obtaining of vertical distributions of temperature, concentration of moisture and some other atmospheric parameters, and also the determination of quantitative characteristics of cloudiness - height of boundary, temperature and three-dimensional structure.

For this it is necessary to create a special device providing the obtaining of initial information with the required accuracy. Theoretical investigations are also necessary, which would permit determining a sufficient set of measurements. No less important is

the development of new methods of forecasting based on information conveyed by meteorological satellites. For the future development of satellite meteorology in our country a series of scientific and research works has been conducted, including investigations on satellites, rockets, high-altitude aircraft and stratosphere balloons and also secondary experimental (field and laboratory) investigations. The complex of equipment designed for solution of several of these problems was installed, in particular, on the "Cosmos-149" satellite ("Space Arrow") and those similar to it. In the brochure we will dwell only on the "Cosmos-149" - the first satellite of the group of space vehicles analogous in the composition of equipment. The experiment carried a research character and was conducted taking into account the short time of active existence of the satellite.

In contrast to the actinometric program of ordinary meteorological satellites, which basically is directed toward the obtaining of total (integral with respect to the spectrum) "departing" radiation of the earth, the program of investigations on the "Cosmos-149" provided for the measurement of radiation in the narrow sections of the spectrum.

For obtaining experimental data about reflected solar radiation on the satellite were installed narrow-angle three-channel telephotometers. One of them scanned the earth, tracing its surface along the flight trajectory, measuring the intensity of reflected solar radiation in three sections of the spectrum: in the band of molecular oxygen - 0.76 nm, in the interval of comparison - 0.74 nm and in the weak band of water vapor - 0.72 nm. The second telephotometer scanned in the plane perpendicular to the direction of flight and measured the intensity of reflected solar radiation in the sections

of the spectrum: 0.34, 0.47, 0.74 nm. The width of spectral intervals, separable by interference filters, was in this case on the order of 50-100Å.

The telephotometers operated cyclically, completing two full revolutions in a period of around 4 seconds. In the first half-cycle the radiation of space and earth was measured and the instrument null ("dark current") was determined. In the second half-cycle there was introduced the standard of brightness, making it possible to control the sensitivity of the equipment in the process of flight, and attenuator, providing measurement of the reflected radiation of the earth in the needed energy range. This range was selected on the basis of the theoretical calculations of the earth's brightness.

The obtained data permitted determining the quantitative characteristics of the angular and three-dimensional structure of the field of brightness of the earth.

The method of determining the characteristics of the vertical structure of the cloud cover - the height of its upper boundary, was original. The method was based on the fact that the relationship of the given measurements in the band of oxygen (0.76 nm) and the neighboring interval (0.74 nm), not having absorption bands, to a certain extent depends on the mass of oxygen on the path of solar radiation having fallen to the cloud and having been reflected from it. And since the concentration of oxygen is constant, its mass depends on the height of the reflecting surface.

Measurements in the band of water vapor permitted evaluating the possibilities of the use of weak bands when determining the mass of vapors in the atmospheric column.

The self-radiation of a planet was measured in the "transparency

window" of the atmosphere (section of the infrared spectrum with wavelength from 8 to 12 nm, in which radiation is slightly absorbed by water vapor always present in the atmosphere) by an infrared radiometer. The angle of the field of view of the instrument comprised about one degree. The original construction of the radiometer, deprived of inlet windows, excluded the thermal interferences from the various parts of the instrument. This permitted measuring the radiation temperature of the earth's surface and the cloud cover with a high degree of accuracy. In the complex with the measurements of the telephotometers the radiometric data permitted determining the height of the cloudiness independently and evaluating the correlation between the reflected solar radiation and the self-radiation of the earth.

The scientific program of the experiment provided also for the measurement, with the aid of the instrument of the radiation balance, of flows of direct and reflected solar radiation in wide spectral intervals (0.3-3 nm and 0.9-3 nm) and flows of the self-radiation of the earth and space in the 3-40 nm interval. Such measurements permit determining the radiant energy remaining on earth and determining all the basic earth processes.

Besides this equipment, on the satellite was installed a television system, providing the obtainment of television images from the nadir region (local vertical) and four transition zones from the earth to space.

Thus, as a result of the launching of the "Cosmos-149" considerable information was obtained about the thermal conditions of the earth's surface and clouds, quantitative characteristics of the cloud cover "connected" to the television images, about angular

and spectral characteristics of the brightness of our planet, observed from space. Investigations of the physical parameters of the lower atmosphere, carried out by the "Space Arrow" - a substantial contribution of Soviet scientists to space meteorology.

In speaking about the investigation of the lower atmosphere, one should also mention the "Cosmos-243" satellite. A global experiment on measuring thermal radio-frequency radiation of the earth and its atmosphere was accomplished for the first time in the world on it. The use of the radio band in geophysical investigations from on board the satellite provides the advantage that the waves of the centimeter band pass without noticeable absorption through clouds which are absolutely non-transparent for visible and infrared radiation and permit determining the characteristics of the underlying surface through a barrier of clouds and precipitation and, in particular, the distribution of temperature over the surface of the world ocean. Waves of the millimeter band are noticeably absorbed by droplets of water which permits not only discovering clouds and precipitation from the radiation spectrum on these wavelengths but also measuring the content of drop water and discovering cells of intensive precipitation hidden by thick clouds. Finally, resonance lines of water vapor are located in the centimeter and millimeter bands. Therefore, in measuring the intensity of radio-frequency radiation on the wave lengths selected accordingly, one can also determine the content of water vapor.

To c 'uct the indicated investigations, sensitive receivers of thermal radio-frequency radiation in the waveband of from 8 mm to 8 cm with antennas directed toward the earth were installed on "Cosmos-243." These receivers and antennas are similar to a great extent to the ground radiotelescopes and differ from them by complete automation.

Also installed on the satellite was a narrow-band receiver of infrared radiation in the band of 10-12 nm. The integrated use of waves of the radio and infrared bands facilitates integration considerably and raises the reliability of the data obtained.

The most reliable results of determinations of parameters of the atmosphere: the content of drop and vaporous water for radiation in the 1.35-0.8 cm bands, were obtained with the flight of the satellite above the water surface of the ocean. This circumstance is especially valuable since information presently obtained about the atmosphere namely above the oceans is very scant. Meanwhile, the oceans are gigantic accumulators of solar energy which they give up in the form of latent heat of evaporation. To a considerable degree, this heat "feeds" with energy the powerful cyclones which determine the weather on the planet.

The brightness temperature of the ocean in the centimeter band is 100-150°K; however, with the presence of ice on the surface of the water the brightness temperature is increased by approximately 100°K, and this circumstance permits discovering ice on the surface of the water. Thus, during the very first days of flight the "Cosmos-243" satellite dependably determined the boundary of the continuous ice around Antarctica. Also obtained was a series of temperature profiles of the surface of the ocean, the integral content of water vapor and drop water was determined in the atmosphere above the ocean along the flight trajectory, and zones of intensive precipitation were isolated.

INVESTIGATIONS OF THE STRUCTURE AND VARIATIONS OF THE UPPER ATMOSPHERE

It is customary to call the upper atmosphere the region which lies higher than 30-40 km above the surface of the earth. However, despite the relative closeness, until most recently it was one of the least studied "envelopes" of the earth. It is necessary to know the

upper atmosphere. First of all, it performs the role of natural radiation protection against penetrating radiation. In the upper atmosphere, ultraviolet, X-ray, and corpuscular radiation of the sun is absorbed to a considerable degree, thanks to which life in its contemporary form is possible on earth. In the variety of physicochemical processes and phenomena which take place in the upper atmosphere, perhaps it has no equal. The ionosphere is a gigantic natural laboratory for the study of processes in plasma in electrical and magnetic fields. The investigation of complex processes of heat- and mass exchange in the upper atmosphere is important for practice; these processes may have an influence on the state of the atmosphere at the earth's surface and, consequently, on the formation of weather and climate. Information on the structure and dynamics of the earth's atmosphere facilitates the interpretation of experimental data about the atmospheres of other planets and the creation of a general theory of planet atmospheres.

The upper atmosphere became an object in direct investigations thanks to the development of space-rocket technology. Already the first information obtained with its use about the upper layers of the air ocean turned out to be important for improving space equipment itself. It is sufficient to present the following fact: when space flights were begun, it became clear that the density of the atmosphere at an altitude of several hundred kilometers is approximately ten times greater than that assumed! And it does not remain constant. Thus, at an altitude of 300 km the values of density may change within broad limits. And this data is necessary for the precise injection of earth satellites into the computed orbits, the creation of systems for the orientation and stabilization of space vehicles, etc.

The accomplishment of automatic docking of artificial satellites in orbit and controlled flight in the upper layers of the atmosphere also requires knowledge of the laws of change of the atmosphere depending on the time of year, local time, etc. It is also necessary to forecast such changes accurately and predict the behavior of the upper atmosphere.

Broad investigations of the upper atmosphere began to be conducted with the use of satellites of the "Cosmos" series.

The density of the atmosphere decreases with altitude very rapidly, and the speed of movement of the satellite is maximum at the perigee. Proceeding from the proportionality of the resistance of the atmosphere to the movement of the satellite (or of the braking), the density of the atmosphere, and the square of the velocity, it is believed that the satellite is slowed down exclusively in the perigee. The resistance to movement on the remaining sections of the orbit is ignored.

The perturbations which act on the satellite as a result of the deviation of the earth's shape from the spherical and the heterogeneity of its gravitational field exceed substantially (by several orders) the perturbations caused by the resistance of the environment. However, in calculating the density of the atmosphere from the slowing down of the artificial earth satellite, it is considered that regardless of magnitude not one of the gravitational perturbations has a secular effect on the large semiaxis of the orbit. Consequently, changes in the sequential times of the satellite's passage through the perigee of the orbit will occur only as a result of retardation. It is necessary to take radiation pressure into account only for an orbit higher than 400-500 km.

Data on the evolution of the orbits of "Cosmos" satellites permitted tracing changes in density in a range of altitudes from 180 to

300 km for almost half the cycle of solar activity. Confirmed, in particular, was the assumption of the dynamic character of the density at altitudes approximately from 200 to 300 km. Fluctuations in the density of the atmosphere (from day to night) were clearly disclosed at altitudes of 270-280 and 200-230 km. The maximum and minimum parameters occur at approximately 1400-1600 hours and 0400-0600 hours local time respectively. In the years of minimum solar activity, diurnal variations are approximately 60-70% at altitudes of 200 km and reach more than 200% close to 300 km, which was not observed at these altitudes during the period of maximum solar activity.

The diurnal variations in density are manifested most sharply at the lower latitudes. Such fluctuations at the lower altitudes in comparison with the period of the active sun are the consequence of the general cooling of the atmosphere and the change in the distribution of the main components by altitudes. Thus, the reduction in the mean density in comparison with 1958 was about two-fold at an altitude of 200 km and 3.5-fold close to 300 km. Beginning in 1965, a gradual increase in atmospheric density above 200 km began which reached maximum value, close to the 1957-1958 level, in the period of the next maximum of solar activity (1968-1969).

It also turned out that magnetic storms have a substantial influence on variations in the density of the atmosphere. Obviously, this is connected with the effect of flows of solar plasma on the earth's magnetosphere.[1] Even relatively weak geomagnetic perturbations have a

[1]Flows of interplanetary plasma are propagated from the active regions of the sun located primarily at some latitude above and below the solar equator. Because of the non-alignment of the plane of the sun's equator and the plane of the earth's orbit, the latter, in its movement along the orbit, intrudes into the region of plasma flows twice a year.

global influence on the temperature and density of the upper atmosphere. In this regard, the relative effect of these perturbations is especially great in the minimum of the cycle of solar activity. During strong magnetic storms, the temperature in the zones of polar auroras may reach more than 3000°K. From the results of an analysis of the braking of satellites in regions of polar auroras, at altitudes of about 300 km an increase in density several times greater than in the lower latitudes is noted.

Blocks of ionization manometers were installed on several vehicles, for example "Cosmos-108," "Cosmos-196," and others to obtain data on the density of the atmosphere by the direct measurement method.

An ionization manometer represents a glass flask to the stem of which a cylindrical grid is fastened. A fine wire is pulled tight within the grid along its axis — a collector of positive ions; a wolfram cathode is fastened to the same stem on the outside of the grid. The cathode is heated to a high temperature and emits electrons which rush for direction toward the positively charged grid. The electrons fly between the infrequent loops of the grid and are repelled by a negatively charged collector. At a certain altitude, the manometer is opened by a special mechanism and its cavity is filled with particles of the external environment. The electrons, accomplishing oscillatory movements near the loops of the grid, collide with the atoms and molecules of the gas which lands in the working cavity of the manometer and ionizes them. The positive ions which are formed are attracted by the negatively charged collector and give up their charge to it. The number of ions formed is proportional to the density of the gas. Therefore, at a certain temperature the current in the circuit of the collector is proportional to the atmospheric pressure.

For investigation of the composition of the upper atmosphere, these same satellites were equipped with mass spectrometers. Serving as the sensitive element of the instrument is the mass spectrometer tube which has access directly to surrounding space with its open inlet. The tube contains a number of fine wire grids — electrodes disposed at specific, precisely fixed distances from each other. The collector in the form of a metal plate is located behind the grids. Collected on the collector are ions which, prior to this, pass through all grids.

The electron block of the instrument generates various constant and alternating voltages which are fed to the electrodes of the tube. The voltages are so selected that only those ions which passed through the tube at some optimum velocity can reach the collector. Ions having a velocity greater or less than the optimum do not reach the collector. The velocity of the ions which pass through the mass spectrometer tube is determined by their mass and accelerating voltage applied to the grids of the tube.

The accelerating voltage changes periodically from zero to the maximum value and, consequently, the optimum velocity is imparted in turn to ions with different mass numbers. When the ions reach the collector, a pulsed current arises in the circuit which is amplified and transmitted to earth by a radiotelemetry system. Simultaneously, data on the accelerating voltage on the grids are transmitted. The mass of the ions is determined by the measurement of this voltage.

If there are ions of only one mass in the environment, the receiving station records one pulse of ionic current for each cycle of change of accelerating voltage. With a more complex composition of the environment two or more pulses are recorded for each cycle.

The composition of the upper atmosphere was also measured on "Cosmos" satellites from the absorption of the sun's ultraviolet radiation using ionization chambers for recording solar radiation in the Lyman-alpha spectral line. This radiation has various degrees of dispersion depending on the concentration of atomic hydrogen of which the outermost regions of the earth's atmosphere consist.

At the present time, we can speak rather definitely about the neutral composition of the upper atmosphere, but not of its variations. The separation of the gases by diffusion begins at altitudes of 100-120 km. At altitudes up to 200-250 km, the basic component of the atmosphere remains nitrogen; however, there is an increase in the relative concentration of atomic hydrogen which is formed with the dissociation of molecular oxygen by solar ultraviolet radiation. The content of molecular oxygen is reduced with an increase in altitude. Beginning at 250-300 km, atomic ogygen becomes the basic component of the atmosphere.

Even higher, beginning with altitudes of 500-600 km in years of minimum solar activity and with altitudes of 1000-1500 km in years of the maximum, the atmosphere becomes helium-hydrogen. Seemingly, the layer with helium in the form of the basic component is observed only in the years of maximum solar activity.

INVESTIGATIONS OF THE IONOSPHERE

The upper layers of the atmosphere, beginning at 80-100 km, which consist of charged particles — electrons and ions — are called the ionosphere.

The ionosphere is a unique conductor of electric current and it affects substantially the propagation of radio waves, partially absorbing long waves and reflecting short waves as a "mirror." The latter circumstance permits implementing short-wave radio communication far

beyond the limits of the earth's visible horizon.

The ionosphere has a complex structure; it is heterogenous both for altitude and for geographic position. The state of the ionosphere and its influence on the propagation of radio waves constantly changes depending upon solar illumination, the time of year, the influence of cosmic radiation, and others. Therefore, for the study of the ionosphere regular observations are necessary which were accomplished from ground ionospheric stations. The appearance of artificial satellites permitted beginning investigations with flight directly in the ionosphere itself or above it, in the interplanetary environment.

From the time of the launching of the first Soviet artificial satellite much new important data were obtained, especially about the outer portion of the ionosphere above the so-called "chief maximum of ionization." It is namely the properties of the "outer" ionosphere which are determinant in implementing radio communication of the earth with space vehicles, radio communication between space vehicles, and the use of artificial satellites for radio communication and television systems. It became clear, in particular, that the ionosphere extends for a distance of up to five earth radii and, perhaps, even more.

The study of the properties of the ionosphere by satellites of the "Cosmos" series was conducted by three basic methods, and namely: direct measurements with the use of traps of particles of various types installed on the satellites; measurements accomplished on earth from the observation of radio signals emitted by the satellite; measurements accomplished with the use of ionospheric sounding from the satellite.

In the ionosphere there are three basic types of free charged particles: positive and negative ions and electrons. The ionosphere is electrically neutral. Therefore, having measured the concentration of positive ions, we can determine the complete concentration of free

charged particles.

On the "Cosmos" satellites, measurements of the concentration of positive ions along the orbit were conducted with the use of three-electrode traps. To exclude possible errors in measurement, traps of various designs were employed on the same satellite. Spherical three-electrode traps are installed on bars above the surface of the satellite, and on the surface — hemispheric and flat traps as well as cylindrical probes which, in addition to the concentration of charged particles, permit measuring the electron temperature. A change in the voltages on the electrodes of these traps and probes causes changes in the currents recorded with their use; a study of the dependences of these currents on the voltages of the so-called "volt-ampere characteristics" permits determining the parameters of the ionosphere.

For a correct interpretation of the readings of the instruments installed on the satellite, it is important to know the positions of the satellite relative to the direction of movement. Determination of the orientation of the satellite was assured by eight flat traps installed on its surface. The flow of electrons which land in the flat trap depends greatly on its attitude relative to the satellite's direction of movement. The comparison of currents recorded in the traps permits learning the orientation of the satellite relative to its direction of movement. Two more special traps of "honeycomb" construction which are sensitive to changes in the attitude of the satellite are installed on the satellites.

At the present time, it has been established that the ionosphere exists primarily because the neutral atoms and molecules in the upper layers of the atmosphere are ionized under the influence of the ultraviolet and X-ray radiations of the sun — they disintegrate into positive ions and free electrons.

However, no simple relation exists between the intensity of the ultraviolet radiation which acts on the ionosphere for a certain time and at a certain altitude and the concentration of charged particles at the same time and at the same altitude. The rate of deionization, i.e., the disappearance of the ions and electrons, depends greatly on the density and chemical composition of the atmosphere.

Study of the connection of the phenomena of ionization and deionization at various altitudes with solar radiation is possible with the passage of the satellite across the boundary between the illuminated and unilluminated parts of the orbit. In this, of course, simultaneous measurements of the intensity of ultraviolet radiation and the concentration of charged particles along the orbit should be conducted. On the "Cosmos" satellites, devices were used which are similar to the traps. The experiment consisted of determining the energy of the electrons emitted by the internal electrode of the device with its illumination by the sun. Since the energy of the photoelectrons depends on the wavelengths of the incident radiation, consequently, we can characterize the intensity of radiation. The energy of the emitted photoelectrons was determined by the "method of counter potentials" which is based on the change in the current of the photocathode depending on the magnitude of the electric field which brakes the photoelectrons. Changes in the field were created by the corresponding changes in voltage on a grid located in front of the photocathode. Thus, the composition and intensity of solar radiation at great altitudes in the range of wavelengths of from 2000 to 5000Å are determined from the energy of the photoelectrons with a certain degree of accuracy.

The measurements conducted on the "Cosmos" satellites with the use of the described equipment permitted obtaining interesting results

pertaining to the structure of the ionosphere and the processes which take place in it.

The concentration of positive ions was measured in the region from 49° North Latitude to 49° South Latitude at altitudes of 200-1550 km. The concentration and temperature of the electrons were determined at altitudes from 200 to 600 km; direct determinations of ionic temperature were conducted. In the daytime, the electron temperature considerably exceeds the ionic temperature as a result of the exchange of energy between the photoelectrons which are formed with the ionization of the components of the atmosphere by solar ultraviolet radiation and the electrons of the ionosphere. This excess is also observed in the nighttime portion of the day; however, it is less. The temperature of the ions fluctuates between the temperature of the neutral component and the electron temperature, in which regard, rather irregularly. In the outer ionosphere, the ionic temperature increases and approaches the electron temperature which, in turn, increases with withdrawal from the sun.

Data were also obtained about changes in photoemission from metals caused by shortwave solar emissions in the altitude interval close to the maximum for ionization of the region of the ionosphere. These changes permitted estimating the integral absorption of the sun's ultraviolet radiation in this region of the ionosphere.

A large quantity of information on the behavior of the ionosphere above the electron concentration maximum was obtained in radiosonding from high-flying satellites on board which the "Mayak" coherent radio was installed. The data pertained to the global distribution of the electron concentration and its dependence on the time of day, latitude, etc. They permitted establishing that the majority of the anomalies

in layer F[1] can be explained on the basis of the idea of ionization drift which leads to the latitudinal displacement of the maximums of electron concentration during the day.

The on-board "Mayak" radio emitted radio waves on two or three frequencies (20.005, 30.0075, and 90.0225 mHz). At the receiving points on earth, special two- and three-channel receivers were located which received the emissions from the satellite and compared the phases. If the radio waves were propagated in an absolute vacuum, the difference in phases of received oscillations would have been the same as at the point of transmission. However, the ionosphere influences the phase of the oscillations in different ways. For example, radio waves with a frequency of 20.005 mHz are substantially subjected to the influence of the ionosphere. At the same time, at a frequency of 90.0225 mHz radio waves are propagated in the ionosphere almost as in a vacuum. Therefore, the difference in the phases of oscillations which have passed through the ionosphere, if it is measured precisely and continuously along the satellite's orbit, is an extremely sensitive indicator of the state of the ionosphere on the path of propagation of radio waves from the satellite to the receiving point. In particular, it directly determines the electron concentration in the region of passage of the satellite at small time segments of seconds and fractions of seconds.

As is known, the interplanetary environment is also a rarefied ionized gas. At the moments when the satellite is located above the ionosphere, the difference in phases also characterizes the electron concentration of interplanetary gas.

[1]F is the region of the ionosphere located higher than 120 km from the surface of the earth; it consists primarily of ionized atoms and oxygen molecules.

Also measured simultaneously with the difference in phases at the receiving points was the strength of the received signals at all frequencies, which permitted obtaining additional data on the state of the atmosphere. This method was used to discover large-scale heterogeneities in the ionosphere with a length of up to 150 km and the spectrum of heterogeneities and gradients of electron concentration were determined.

The smallest dimensions of heterogeneities disclosed in processing the records are about 500 m. They were recorded primarily during ionospheric disturbances. Quite frequently, the heterogeneities were located in limited regions of the ionosphere with horizontal dimensions from several tens to several hundred kilometers. In a number of cases lens heterogeneities were recorded at altitudes of 250-350 km.

Information was also obtained on angles of refraction of radio waves in the ionosphere. At a frequency of 20.005 mHz, the angle of refraction changed from zero to 3-5°. The angle of refraction was reduced with a reduction in the dimensions of heterogeneities of the atmosphere along the orbit.

In recent years, for investigations of the ionosphere they began to use methods based on an analysis of the effect which it has on the propagation of super-long radio waves with a wavelength of from several to hundreds of kilometers; this method permits investigating both its lower and its upper regions.

Under the influence of the earth's magnetic field, the ionosphere becomes "transparent" for radio waves with superlow frequency to a considerable degree. In this, the attenuation of the radio waves which penetrate into the ionosphere from the earth's surface depends primarily on the state of its lower layers. Measuring on board the satellite the intensity of the signals of the ground radio stations

which operate within the range of super-long waves, we can determine the absorption of the waves and estimate the concentration of charged particles in the lower regions of the ionosphere.

The earth's magnetic field also causes a second special feature of the propagation of super-long waves in the ionosphere — magnetic lines of force which seem to be guide rails along which the radio signals move. Having penetrated into the ionosphere, for example in the Northern Hemisphere, these signals are removed from the earth's surface to a distance of 3-4 earth radii and return to the earth in the Southern Hemisphere close to the conjugate-magnetic point. Since the main portion of the path of the super-long waves lays in the upper layers of the ionosphere, the signals of this frequency band are a unique and sensitive probe for investigating its upper regions.

Such experiments were conducted, in particular, on the "Cosmos-142" and "Cosmos-259" satellites. The orbits of the satellites permitted conducting measurements in the region of latitudes bounded approximately 50° north and south of the equator and at altitudes of from 200 to 1350 km from the earth's surface. Measurements were accomplished both with the passage of the satellite above the zones of disposition of the radio stations as well as at great distances from them in the conjugate-magnetic points.

In the process of the experiment which was conducted at various times of the day, the on-board receivers received the signals of the radio stations in the entire band of frequencies selected for investigation. The measurements showed that attenuation of the super-long radio waves during passage through the lower ionosphere in the nighttime is not great and depends little on frequency, and in the daytime is considerably greater that at night and increases rapidly with an increase in frequency.

An analysis of the measurements of the intensity of the signals received in the conjugate-magnetic points showed that it changes rapidly in time and has a "ruptured" appearance. "Splashes" of intensity in many cases are separated by a distance on the order of several hundred kilometers. The results obtained, possibly, indirectly confirm the non-uniformity of the structure of the upper atmosphere.[1]

Further experiments on satellites of the "Cosmos" series unquestionably will lead to a more profound understanding of the structure of the ionosphere and the physical processes which take place in it.

STUDY OF CORPUSCULAR RADIATION

Experiments begun on the third Soviet satellite on the study of electrons with energies of about 10 keV permitted discovering for the first time, at altitudes of 1000-1800 km in the nighttime, fluxes of soft electrons and confirming the importance of the role of corpuscular radiation for the basic processes in the upper atmosphere. The task for further investigations which was assigned to the "Cosmos" satellites was the detailed study of the energy spectrum of the electrons and the obtaining of information about the ion beams and distribution of geoactive corpuscular radiation in space and its connection with various geophysical processes: with geomagnetic disturbances, polar auroras, more rigid radiation, variations in the density of the upper atmosphere, and

---

[1] In recent years, some well-known scientists have expressed the assumption that the upper ionosphere has a "fibrous" structure. In accordance with this hypothesis, individual "fibres" are oriented along the lines of the earth's magnetic field and are regions of increased ionization. Since the trajectories of the super-long waves are close to the magnetic lines of force, such "consolidations" of ionization should have a substantial influence on their propagation.

solar activity.

The first such experiments were conducted back in 1962 on the "Cosmos-3" and "Cosmos-5" satellites. In essence, these satellites were a prototype of a geophysical station with a long service life and large data capability. "Cosmos-3" and "Cosmos-5" were intended primarily for the investigation of geoactive corpuscles above the equatorial and middle latitudes where their role is least studied.

The sensors of the satellites could effectively register protons with an energy of from 100 eV to 10 keV and electrons with an energy from 1 to 20 keV. The protons were registered with the use of special traps with magnetic filters, and the electrons - with the use of fluorescent screens enclosed in opaque aluminum foil. The radiation from the fluorescent screens was converted to electric current by means of photomultipliers. The lower threshold of energy of the protons being registered was changed by an electric filter fed by an intermittantly changing high "braking" voltage. The lower threshold of energy of the electrons being registered was also changed by an additional intermittant voltage which accelerates the electrons. All this permitted estimating the effective energy of the corpuscles.

The corpuscular sensors also react to electrons and protons with an energy exceeding 10-20 keV. But the effective energy of individual particles cannot be estimated by them.

The electron sensors practically do not react to X-ray radiation which arises in the surrounding atmosphere or in the body of the satellite under the influence of rigid electrons with energy which exceeds tens of kiloelectron-volts. This provided the more unambiguous decoding of the signals being registered.

For reliability, the corpuscles were registered by several

sensors arranged on the outside: protons - by two and electrons - by five. For an additional check, aluminum foil of various thicknesses was employed on the electron sensors.

Main attention in the experiments was concentrated on determining the anisotropy of the corpuscular beams with various charges. The input openings of the indicators had a small solid angle and their axes were arranged in opposite directions and perpendicular to each other. The rotation of the satellite around the center of mass changes the directions of the input openings of the indicators, assuring the sounding of corpuscular beams from any directions of space.

For the determination of the orientation of the sensors relative to the lines of force of the geomagnetic field, special indicators of direction to the sun were installed on the satellites. These same solar indicators served for checking micrometeor erosion of the opaque films on the fluorescent screens of the electron indicators. The strikes of the micrometeors against the fluorescent screen causes splashes from the radiation which are registered. But after them, microapertures remain in the foil through which sunlight can penetrate to the photocathode of the multiplier. The increase in the current of such an electron indicator with its direction at the sun serves as a measure of the increase in meteor erosion. When the electron indicator is not directed at the sun even with the presence of holes from micrometeors in the foil, light does not penetrate to the photocathode and only the corpuscles are registered.

Work was conducted in the direct transmission mode as well as in the storage mode. In the first case, the corpuscle sensors were in the high-frequency field of the transmitter antennas. This circumstance permitted clarifying that the effect of the high-frequency field of radio transmitters on the registering of geoactive corpuscles of even

the smallest energies was absent.

In addition to the corpuscular sensors, Geiger counters shielded by lead were installed on the satellites. The counters registered protons with energy exceeding 50 MeV and X-ray and gamma radiation with energy exceeding 100 keV. Analysis of measurements along the orbits of the satellites permitted disclosing several groups of the most intensive corpuscular beams not connected with each other at altitudes primarily at 500 km in the region of geographic latitudes of $\pm 49^{\circ}$.

Pertaining to the first group are protons with energy on the order of 50 MeV, the registered flows of which comprised approximately 10^{4} particles$\cdot$cm$^{-2}\cdot$s^{-1}. The second group was electrons with an energy of about 100 keV which comprise the basic component of the inner zone of the radiation belt. Their total flows reached values of $20\cdot 10^{7}$particles$\cdot$cm$^{-2}\cdot$s^{-1}. Finally, the third group is a group of electrons of mean energies (about 15 keV), the noticeable intensities of which were observed only above 500 km.

Softer particles were also discovered — electrons with energies of only several tens of electron-volts which are formed with the ionization of the upper atmosphere by solar ultraviolet radiation. Of especially great interest is the study of geoactive corpuscles of low energies in the Arctic latitudes. Electrons with energies of several kiloelectron-volts are the main agent which causes the polar auroras, in which regard, the most mobile and beautiful of their forms. The spectrum of these electrons often has a clearly expressed maximum at an energy of about 5 keV, but there are also more complex spectrums. Low-energy protons are responsible for the formation of weakly luminous extended forms of polar auroras. Directed by the lines of force of the geomagnetic field, these particles intrude into

the atmosphere in gigantic thousand kilometer jets. In this, its warming up and swelling occur especially in the Arctic latitudes, electrical fields and currents arise in the magnetosphere and ionosphere as well as in the oceans and poorly-conducting soil, low-frequency electromagnetic and infrasound waves are formed, and others.

However, the problem of the origin of the polar auroras and magnetic storms is still far from solved. The main reason is the insufficiency of experimental data. This pertains first of all to the characteristics of geoactive corpuscles which cause the auroras, their intensity, distribution by energies, and character of motion in the geomagnetic field. Naturally, such data can be obtained only on the basis of satellite measurements. For their correct interpretation, it is necessary to know the course of development of the polar aurora and its basic effects which are manifested before and after the fly-by of the satellite. Therefore, the conduct of simultaneous measurements from on board the satellite and at many geophysical observatories and stations which supplement each other is very important. It is just such a complex and multipurpose experiment which was conducted on the "Cosmos-261" satellite. It was injected into polar orbit with an angle of inclination to the plane of the equator of 71°. On board was equipment for studying the geoactive corpuscles which cause the polar auroras, electrons of superthermal energy, and variations in the density of the upper atmosphere during the auroras. Simultaneously, the network of ground geophysical stations performed motion picture photography of the polar auroras on the celestial concave, recorded brightnesses and altitudes, determined some of the characteristics of the intruding energy particles, and measured the temperature of the upper atmosphere.

During the aurora some, true, small fraction of the electrons is accelerated to very great energies — right up to several million electron-volts. Their intrusion leads to an abrupt increase in the absorption of radio waves in the lower ionosphere and, in the Arctic regions, also at times to the disappearance of radio communication. Therefore, in the process of the experiment great attention was devoted to the measurement of the characteristics of the ionosphere which are connected with these effects. In particular, the non-uniformity of ionization of the upper atmosphere and the geographic propagation of the phenomena of absorption of radio waves were investigated. Simultaneously, the intensity of the energy particles which intrude into the atmosphere was measured from the satellite.

At moments of especially intensive polar auroras, with the collisions of power electrons with atoms of the atmosphere braking X-ray radiation arises. It was registered during the period of operation of the satellite by special equipment which was lifted into the stratosphere on sounding balloons to altitudes of more than 20 km.

The measurement of superthermal electrons was extremely interesting since it permitted comparing data from direct registrations on board the satellite with other observations of the ionosphere in this period. In this regard, if on "Cosmoses 3 and 5" the measurements of the photoelectrons were conducted at the low and middle latitudes, measurements on "Cosmos-261" were extended to the higher latitudes where one could expect new effects connected with the movement of photoelectrons in the excited polar ionosphere and their emergence into the magnetosphere.

Thus, much data has already been obtained which brought the scientists closer to an understanding of the nature of the polar auroras.

INVESTIGATIONS OF RADIATION AT LOW ALTITUDES

The study of the radiation situation at relatively low altitudes above the earth's surface has great practical and scientific significance. From the practical point of view, detailed investigations of radiation at altitudes of 200-400 km are necessary to assure the safety of flights of piloted space ships. From the scientific point of view, such investigations are important for the study of the structure and dynamics of the radiation belt because it is at these altitudes that the interaction of the particles of the radiation belt with the earth's atmosphere becomes substantial and the non-dipole quality of the geomagnetic field has a strong effect.

Observations of the level of ionizing radiation were already conducted on the very first satellites of the "Cosmos" series, in particular on "Cosmoses-2, 7, 9, 10," etc. Radiometers were installed on board the satellites whose composition included Geiger and scintillation counters. Beginning with "Cosmoses-12 and 15," they began to use electrostatic analyzers for an analysis of the energy spectrum of the particles.

The main part of the analyzer is the spherical or cylindrical deflecting capacitor to the plates of which constant potentials are fed. Particles whose energies lie within a given interval may pass through the gap of such a capacitor. Thus, the capability to measure a differential spectrum is contained in the very design of the electrostatic analyzer. The potentials on the deflecting plates of the analyzer are considerably less than the corresponding energy of the particles being analyzed. The registering device of the electrostatic analyzer is protected from the incidence of direct sunlight. To prevent the landing of thermal ions of the ionosphere in the operating gap the entry of the analyzer is closed by a grid to which a positive

potential relative to the body of the satellite is fed.

Thanks to the long measurements with the use of "Cosmos" satellites, possible doses of radiation at altitudes of about 300 km were determined depending on the conditions of geomagnetic and solar activity. The radiation safety of impending flights of the "Vostok" and "Voskhod" space ships was proven on the basis of these data. The results of the measurements permitted obtaining a detailed picture of the planetary distribution of radiation and creating the first dosimetric maps for low altitudes of the inner and outer zones of the radiation belt.

Tests conducted on the second and third space ships disclosed the clear special features in the distribution of intensity over the earth in the form of sectors with an anomalously high radiation intensity. In particular, the South Atlantic anomaly and the anomaly with its center in the region of the Bering Sea were discovered as a result of investigations on the second Soviet satellite ship. Subsequent analysis conducted, in particular, with the help of satellites of the "Cosmos" series showed that the existence of sectors with increased radiation intensity is explained by the appearance of outer and inner zones of radiation of the earth. The geographic distribution of these sectors, just as the intensity in them, is completely determined by the special features of the actual geomagnetic field. An important discovery was the establishment of the fact that a subsidence of the inner as well as the outer zones of the belt is observed in the region of the South Atlantic. Great significance was also had by the experimental determination of the equator of cosmic rays.

Of the other results obtained using the "Cosmos" satellites we should note the establishment of the dependence of the position of the intensity maximum of the outer zone of the radiation belt on the mag-

netic situation. With an increase in the magnetic disturbance, the maximum is displaced toward the earth. The dependence of the mean daily intensity caused by the radiation belt on altitude was determined. Thus, in an orbit with an apogee of 407 km the intensity turned out to be 5.6 times greater than in an orbit with an apogee of 301 km.

During the flight of the satellite "Cosmos-4" in April 1962, an increase in the counting speed of the Geiger counter of approximately 4 times was discovered in comparison with the measurements on the second orbital spacecraft in August 1960. This agreed with the theoretical hypotheses about the change in the intensity of protons in the inner zone of the belt with the transition to the minimum of solar activity.

An artificial radiation belt was formed as a result of the high-altitude "Starfish" thermonuclear burst conducted in the United States on 9 July 1962. It concentrated at the lower altitudes, primarily in the region of the Brazilian magnetic anomaly. This made possible its study with the use of satellites of the "Cosmos" series. Measured were the average times of life of the electrons in the artificial radiation belt for various magnetic shells which, as it turned out, depend basically on altitude. The values of the absolute fluxes of these electrons as well as the energy spectrum of the captured protons and their fluxes were obtained.

During 1965-1967, with the use of "Cosmos" satellites measurements were conducted of the fluxes and energy spectrums of heavy charged particles and neutrons using nuclear emulsions. The layers of the nuclear emulsion were assembled in stacks of 15-20 pieces each with a diameter of 50 mm and were placed inside round, airtight aluminum containers. The stacks were fastened in airtight compartments of the satellites and were also inserted inside polyethylene spheres with a radius of 5, 10, and 15 cm disposed here. The latter were intended for investigating the attenuation and accumulation of radiation in tissue-

equivalent matter. The results obtained were used to compute doses of cosmic radiations. In particular, doses of neutrons within the compartments of the satellite were calculated on the basis of the measured spectrums. According to these calculations, the neutron yield to the total dose in Rem units is 10-15 percent.

Satellites of the "Cosmos-41" type permitted investigating the radiation captured in the earth's magnetic field up to altitudes on the order of 40,000 km above the surface of the earth.

INVESTIGATION OF THE SUN'S SHORTWAVE RADIATION

Information obtained about the upper atmosphere and near space is used in practice, for example, for calculating the time of existence of the satellites, forecasting radio communications, compiling the thermal balance of the lower and upper layers of the "air ocean," etc.

The sun is the basic source of energy placed in the atmosphere, and its study, naturally, has great significance for geophysics.

It is necessary to record systematically some of the characteristics of the sun which are connected with solar activity but inaccessible to observations from the ground. There is also a basis to assume that X-ray flares are generated in the outer regions of the sun and closely linked with perturbations in the corona which lead to corpuscular flashes which are dangerous for space flights.

Corpuscular beams are propagated more slowly than X-ray radiation because of the lower speed of the particles and their longer flight trajectory. Thus, in principle it appears possible, by recording X-ray flares, to give the cosmonauts warning of from several minutes to an hour or more concerning the approach of radiation danger -- beams of corpuscles. Such a warning will permit the crew of a ship located in open space or on the moon to take the necessary measures: to take cover in a special shelter, to turn the ship with its protected part in the direction of movement of the corpuscles, etc.

Investigations of the sun's shortwave radiation were conducted on special "solar" satellites of the "Cosmos" series. They represented a modification of a unified satellite with the orientation of one of its axes on the sun. The composition of the onboard equipment

included an X-ray heliograph with a slotted collimator and an X-ray photometer.

The X-ray heliograph consisted of two identical sensor units disposed on the outer surface of the satellite and an electronics unit installed in an airtight compartment. Geiger counters of X-ray photons served as the radiation receivers. Pulses from the counters were recorded by the electronic circuit of the logarithmic intensimeter. Voltage was fed from the input of the intensimeter to the input of the telemetry system.

The X-ray photometer consisted of sensor units disposed on the outer surface of the satellite and an electronics unit installed in the airtight compartment. Geiger counters of photons with additional filters were used as radiation receivers. Three counters were sensitive to the mild X-ray region of the spectrum and one counter, practically insensitive to the sun's X-ray emission, served to check the level of interference from particles of the radiation belt. The optical axes of all counters were parallel to the axis of the satellite which was oriented on the sun. The readings of each counter -- speed of counting of the pulses -- were recorded using a logarithmic intensimeter. The output voltages of the intensimeters were recorded by an on-board memory unit through a commutator with an interrogation rate of 10-20 seconds. To tie the results of the measurements to the illuminated sections of the orbit, the composition of the instrument also included an optical sensor of the sun.

The satellite was oriented on the sun with a precision of 1-2° on each turn after emerging from the earth's shadow, and this orientation was retained during the entire time that the satellite was on the illuminated portion of the orbit. Three times during each turn the axis of the satellite intersected the sun's disk with an average velocity of 0.04° per second. When the axis of the satellite intersects the sun's disk, its image is obtained in two mutually perpendicular directions. To tie the records obtained to specific sectors of the sun, optical sensors were used which fixed precisely the moments of passage of the edges of the solar disk across the field of view of the counters.

With the use of equipment installed on board the satellite, an investigation was conducted of the regions of generation and the spectral composition of the X-ray flares on the sun and the dynamics of development, electron temperature, and electron density of the active regions in the absence of flares were studied.

In particular, the investigations showed that with a "quiet" sun the intensity of radiation in the very shortwave band of 1.5-4 Å practically equals zero and increases sharply at the moment of microburst of the X-ray radiation. Radiation in the band of 4.4-6.5 Å changes within lesser limits, and radiation in the "mild" band (8-14 Å changes unessentially.) The increase in intensity occurred almost simultaneously in the regions of 1.5-4 and 4.4-6.5 Å.

The electron temperature of the radiating region was determined on the assumption of a thermal mechanism for the generation of the radiation of microflares with respect to the readings of counters with different spectral sensitivity. For small bursts, it was about $10^{7°}$ K.

The altitude of the active X-ray region measured according to the X-ray overshoot of the limb turned out to be equal to 20,000--80,000 km and the altitude of the X-ray flare 20,000-25,000 km. The region of X-ray flare usually had a fibrous structure with an angular diameter of the fibres of about 10 s similar to the structure of the regions of optical flares.

As a rule, the X-ray flares were located just above the so-called active regions of our heavenly body with characteristic groups of spots observable with the aid of ground optical means. Interestingly in a number of cases the presence of two centers at one flare approximately identical in brightness was revealed. The distance between them was about 6 angular minutes.

INVESTIGATION OF METEORIC MATTER

The study of meteoric matter which arrives in the earth's atmosphere and near-earth space from interplanetary space is of

interest to geophysics. From this point of view, it is first important to clarify their role in the processes which occur here. Therefore, most significant are investigations of the general flux of meteoric particles and the spectrum of their energies and mass. Moreover, a particle with a mass of even thousandths of a gram with its tremendous velocity of movement may produce noticeable destruction of the spacecraft. Collisions with even finer particles lead to the gradual erosion of the shell of the body and optical, light-sensitive, and other unprotected surfaces of instruments installed on-board the craft. An estimate of the meteoric danger is necessary in working out the design of automatic and inhabited stations.

Equipment for recording meteoric particles with piezoelectric sensors of barium titanate or ammonium phosphate was installed on geophysical rockets and the third Soviet satellite.

A ballistic piezoelectric sensor is a massive plate suspended on a flat spring to which several piezoelectric elements have been fastened. Sensors of such a type are capable of recording the strikes of meteoric particles having a mass of up to one billionth of a gram with a velocity of about 40 km/s. With the displacement of the plate under the influence of a strike of a meteoric particle, the piezoelectric elements convert the mechanical energy of the particle to an electrical signal in the form of brief damped voltage oscillations. The signals go from the piezoelectric sensors to a special converter which provides their division into several bands for amplitude and the calculation of the number of signals in each band. Division by amplitude is accomplished by tapping the signal from various cascades of the amplifier to the counting device of each band.

A similar apparatus for the conduct of micrometeoric investigations was subsequently employed in flights to the moon on the "Electron" automatic interplanetary stations. The measurements which were accomplished led to conceptions of the high concentration of dust in near-earth outer space and the hypothesis of the existence of a dust cloud of the earth based on them, the density of particles in which is immeasurably higher than in interplanetary space. In this connection, it should be expected that the meteoric danger in near-earth orbits

is greater than on interplanetary routes.

Soon direct confirmation of the meteoric danger was also received. In 1958, the American satellite "Explorer-3" was damaged when passing through the meteor stream Aquarids. The equipment of the Soviet "Luna-3" automatic station recorded the hitting of a large particle and ceased the transmission of information immediately after this. But then by the middle of 1967 the overall number of satellites and interplanetary stations approximated 800. However, instances of the damage of spacecraft as a result of collisions with meteoric particles were no longer observed.

Experiments in which observations of micrometeorites were connected with the recording of destruction of the material of the detector with ultra-high speed striking of the particles provided the size of the streams of dust particles in near-earth outer space three orders less than in tests with piezoelectric detectors.

In 1966, on satellite "Cosmos-135" measurements of a stream of particles of cosmic dust were also conducted with the use of piezoelectric detectors. However, special measures were adopted to increase the noise stability of the equipment. Two identical instruments stood on the satellite to record the collisions with micrometeors. The sensors of one instrument were located directly on the inner surface of the satellite shell while the sensors of the other were installed on a special remote panel thoroughly insulated acoustically from the body of the satellite.

For recording collisions, use was made of the high-frequency component of an electric signal which arose in the sensor under the influence of accelerations with the propagation of the elastic deformation wave along the surface monitored by the sensor. Amplification of the signal was accomplished at a high frequency since the collision time was small and the spectrum of the mechanical noise of the satellite equipment is usually maximum in the region of low frequencies. The acoustical insulator which protected the remote panel attenuated the noise which comes from the satellite in the region of the operating frequencies by 60 dB. In each instrument, two identical sensors were

used with independent amplification channels connected to a coincidence circuit. Considering the high sensitivity of the equipment, the use of coincidences permitted a considerable reduction in the danger of recording noise and stray currents. Suppression of external electromagnetic interference was attained, apart from thorough screening, by the introduction of signal selection for duration. A strictly periodic feeding of a calibrated acoustic pulse which simulates a collision was envisioned to check the working order of the instrument during its operation in flight.

The instrument with sensors on the insulated remote panel recorded the first "collision" only on the 87th loop of the orbit. Altogether, 141 events were recorded during 630 hours of measurements. Of them, only four could be considered with some probability as the result of actual collisions with micrometeors. The remainder are unambiguously the consequence of interference which arose in the system and pertain for time to the moments when the satellite emerges from the region of the earth's shadow.

The readings of the instrument and sensor which was situated on the inner surface of the satellite body, i.e., they were not insulated, had a different character. The instrument gave 205 signals during 150 hours of operation. In this, the maximums of the events were observed in periods of sudden change in the thermal conditions- with the satellite's emergence onto the section of orbit illuminated by the sun and when entering the earth's shadow. It is completely obvious that the sensors of the second instrument recorded primarily noise of thermal origin. It was practically impossible to distinguish from them the very rare signals which correspond to collisions.

In the summer of 1967, measurements of a stream of micrometeors in near-earth outer space with the use of anti-interference acoustical detectors were conducted on the satellite "Cosmos-163." During 1370 hours of observations, three collisions were recorded on a level of mass of two billionths of a gram. The magnitude of the stream of micrometeors thus corresponds to $2.5 \cdot 10^{-6}$ particles on one square meter. These data completely confirm the results of the measurements on "Cosmos-135" which refuted the hypothesis of the existance of a

dust cloud around the earth.

MEASUREMENT OF THE EARTH'S MAGNETIC FIELD

The earth's magnetic field was also an object which enjoyed the attention of the "Cosmos" satellites. Data on the magnetic declination were widely used for mineral prospecting, and in navigation and aviation. However, measurement of the magnetic field is exceptionally laborious and requires much time. It is accomplished by various methods: ground instruments, aeromagnetometers, measurements on a non-magnetic ship, magnetometers towed behind ships and contained in non-magnetic gondolas. Artificial satellites permit conducting a magnetic survey much more rapidly and over a considerably greater portion of the earth's surface. Their role is especially great in the study of the secular course of the earth's magnetic field.[1] It is different in different regions of the earth, having changed with time in the very same place, and depends on the level of magnetic and solar activity. Study of the secular course has tremendous significance for knowledge of the internal structure of the earth and the nature and origin of the geomagnetic field. Charts compiled even from detailed and dependable measurements over some time no longer reflect the true distribution of the field. Knowing the regular laws of change of the secular field, scientists could also forecast changes in the geomagnetic field over the surface of the earth and refine magnetic charts effectively.

Proton magnetometers were used on the "Cosmos" satellites. Measurement of the magnetic field with their use is reduced to measuring the frequency of the free precession of the protons in the earth's field being measured.

Two magnetometers were installed on each satellite, the sensors of which were oriented at an angle of 90°. The instruments

[1]Secular course - slow secular changes in the earth's magnetic field. Their most important features are a reduction in the general magnetic moment of the earth and the earth's systematic drift to the west. Thus, over the last 100 years the earth's magnetic moment was reduced by 5 percent while the magnetic pole of the dipole part of the field shifted along the parallel 5° to the west.

were switched on in turn from a precisely time-programmed device with an interval of 32 seconds. The time markers permitted tying the on-board readings of each of the instruments to absolute time. The sensors of the magnetometers were separated from the body of the satellite which contained magnetic parts on a special remote bar. At the places where the sensors were placed, a sufficiently uniform magnetic field was created with the use of a system of permanent magnets which compensated for the magnetic influence of the satellite.

As is known, measurements of the earth's magnetic field in its immediate environs at altitudes of from 230 to 800 km were first conducted in 1959 on the third Soviet artificial earth satellite. In 1959, magnetic measurements in the altitude range of 500-3500 km were accomplished by American scientists using the "Vanguard-3" satellite. However, both sets of measurements were conducted over comparatively irradiated spaces of the earth: the third satellite - over the territory of the Soviet Union, "Vanguard-3" - over individual regions of the United States, Latin America, and Australia. A large portion of the earth remained uninvestigated, especially the world ocean. This is explained, in particular, by the fact that with the proton magnetometer which was installed on the "Vanguard-3" satellite the measurement of the frequency of the free precession of the protons was accomplished by a ground frequency meter. Consequently, measurements could be conducted only in the zone of direct visibility of the satellite, in regions of a limited number of ground stations.

On the "Cosmos" satellites, measurement of the frequency of the free precession of the protons was conducted directly on-board. This permitted using a memory device in which the results were recorded in the form of a coded number and conducting measurements over the entire orbit. As a result of the launching of "Cosmos-26" and "Cosmos-49" alone 75 percent of the earth's surface was captured for the first time by magnetic survey, in which regard, practically simultaneously. Subsequent launchings of "Cosmos" satellites with caesium magnetometers on board into Arctic orbits made possible the global magnetic survey of the earth.

TELESCOPES IN SPACE

As is known, it is impossible to observe regions of the spectrum of electromagnetic waves shorter than 3000Å from the surface of the earth. At the same time, the ultraviolet and X-ray bands are of extreme interest to astronomers who are studying the hot and, consequently, cold stars, interplanetary, interstellar, and intergalaxy medium, etc. The brightest, so-called resonance lines of almost all elements lie in this region of the spectrum. Also lying here is the maximum radiation of the hot stars with surface temperature exceeding 20,000°C.

With the help of "Cosmos" satellites, the Soviet scientists were the first to obtain the opportunity to carry their telescopes beyond the limits of the absorbing atmosphere and conduct observations in the waveband from the visible to the ultraviolet portion of the spectrum.

What will these investigations provide? First of all, the scientists hope to clarify the nature of the sources of X-ray emission discovered about 10 years ago. Now about half a hundred such sources are known, the overwhelming majority of which up to now have not been identified with any known optical objects. It is expected that telescopes lifted into space will help disclose their secret.

Of tremendous scientific interest are spectroscopic observations of ultraviolet rays. There is the opinion that the rarefied gas located between the galaxies radiates namely in this spectral region. As a result of further experiments, we may be able to draw conclusions concerning its density.

The enumerated questions face exoatmospheric astronomy. "Cosmos-215" was also launched for the solution of some of them. The satellite was put into a low orbit - altitude at the apogee was 426 km. Such an orbit was selected so that the flight proceeded below the radiation belt. Otherwise, the particles of the belt would have created a strong "background" which would have introduced interference into the recording instruments and hindered measurements.

The satellite was equipped with small telescopes with a mirror diameter of 70 mm for observations of the emission of hot stars in various bands from the visible portion of the spectrum to the ultraviolet portion with a wavelength of 1225 Å; with an X-ray telescope which recorded the radiation in the spectral region from 0.5 to 5 Å; and with two photometers for recording the solar radiation scattered in the upper atmosphere of the earth.

A complex experiment on investigating the entire spectrum of electromagnetic waves shorter than 3000 Å was also conducted on satellite "Cosmos-262." In essence, this satellite became a small optical observatory equipped with instruments for the recording of vacuum ultraviolet and mild X-ray radiation of the sun, stars, interstellar medium, and upper atmosphere of the earth simultaneously.

On the satellite there were three 16-channel photometers. These instruments were intended for the study of the VUF (vacuum ultraviolet) and MR (mild X-ray) emissions of the sun, and the cosmic background and upper atmosphere of the earth in 16 spectral intervals. The intervals were selected in such a way as to investigate the radiations from the "quiet" regions of the outer envelopes of the sun and the areas and intermediate regions disturbed by bursts. Moreover, these instruments recorded radiation from the main element of the sun's atmosphere - hydrogen and general integral radiation. The spectral intervals were distinguished using automatically shifted filters. They were recorded by one receiver which increased the accuracy of measurements in comparison with the method in which each interval has its own receiver.

The other group of instruments included two 10-channel photometers with different fields of view. They were arranged parallel to each other. This equipment was intended primarily for an investigation of the emissions of the stars, the interstellar medium, and the earth's upper atmosphere. In order to investigate the stars and interstellar medium the instruments had to possess very small fields of view and high sensitivity, which was provided by special parabolic mirror lenses which concentrate the emissions from the stars on a special diaphragm. The changeable diameter of the aperture in the diaphragm determined the desired size of the field of view.

The representative of the third group of instruments was a spectrometer for investigating the spectrum of the sun's radiation. It was required to aim it exactly at the sun. Therefore, a special tracking system for automatic aiming was developed for the instrument. Its design envisaged a specific logic of operation: search began only in the case where the sun "landed" in the "field of view" of the tracking system. Thus, the useless expenditure of electric power on the "night" side of the orbit or when the spectrometer was in the shadow of the satellite's body was excluded.

It was extremely important to determine the orientation of the observatory in space correctly and precisely for the successful decoding and processing of the information. This task was solved by a complex of instruments whose composition included elements of scientific equipment sensitive to the sun's light, sensors of the angles of aiming the spectrometer at the sun, and a magnetometer. The information obtained permitted establishing dependably the directions from which emissions were recorded at one moment of time or another.

STUDY OF COSMIC RAYS

An important place in the program of scientific investigations on satellites of the "Cosmos" series is occupied by the study of cosmic rays. For this, continuous measurements were conducted for a long time on satellites with the same type of construction and scientific equipment put into near orbits sequentially at a halfyear interval. The launching of the next satellite was accomplished prior to completion of the calculated stay time of the preceding one in space and the space objects were at the same altitudes in the area of approximately the same latitudes for a certain time. Then the readings of the instruments and sensors installed on different satellites with their operation under the same conditions were compared. Such measurements of a patrol character were conducted first.

A measurement complex was installed on board the satellites which consisted of a circular counter unit and an ionization chamber. The first instrument was a system of gas-discharge counters. The

central counter was disposed along the axis of a cylindrical wolfram filter with a thickness of 8 mm. Twelve external counters surrounded by a duraluminum two-millimeter screen were arranged around it tightly touching each other and the outer surface of the cylinder. Each external counter forms a double coincidence telescope with the central counter which records the particles which have gone through 8 mm of wolfram. Altogether, there are 12 such telescopes in the instrument.

The central counter and each pair of external counters, the filaments of which are arranged in one diametric plane, form six triple coincidence telescopes which record particles which have gone through 16 mm of wolfram.

With the interaction of the primary particles with the wolfram substance of the filter, showers may occur in the latter. The secondary particles generated in this case will be recorded by all sensors of the instrument. To consider the showerly cases, five external and a central counter are allotted in the circular unit which together form a six-fold coincidence system.

The ionization chamber is an omnidirectional detector. Its important property as a sensor is the stability of parameters over several years of continuous operation. Gas-discharge and scintillation counters do not possess such properties. The chamber was made of steel 0.04 cm thick. Its volume of 3000 cm^3 was filled with argon of high purity under a pressure of 8 at. The collecting electrode in the form of a rod with a steel ball located in the center of the chamber was fastened in its throat on an insulator.

Reception of telemetry signals from on board the satellites was conducted in a zone of geomagnetic latitudes of 39-26° and in an altitude interval of from 250 to 520 km.

In this experiment, it was possible to use the earth's magnetic field as a spectrum analyzer of magnetic rigidity and obtain data on the time distribution of the intensity and ionizing capability of cosmic rays in some intervals of the energy spectrum and their ties with various geo- and heliophysical phenomena.

Equipment was installed on a number of "Cosmoses" to measure electron fluxes of various energies. Such an experiment was conducted, in particular, on the satellite "Cosmos-225." It was used to investigate electron fluxes as part of cosmic radiation at altitudes greater than 200 km. These measurements showed the existence of an excessive background of electrons, thereby confirming the results obtained on earlier experiments, in particular, on the "Proton" satellite. Fluxes of various groups of nuclei during the period close to maximum solar activity were also investigated in flight. Data were obtained about the relative fluxes of various groups of nuclei and the variation in these fluxes.

Determination of the charge and energy of the particles from their deviation in a magnetic field may serve as one of the means for analysis of cosmic rays. But sufficiently strong and extended magnetic fields are necessary for this. On board artificial earth satellites and automatic interplanetary stations they may be obtained using superconducting solenoids.

As is known, the phenomenon of superconductivity consists of the fact that the electrical resistance of some materials practically disappears with their cooling below a certain, so-called critical temperature. Superconducting properties are manifested only at very low temperatures close to absolute zero. The superconducting devices now used in practice are therefore cooled in special vessels - cryostats - with liquid helium. The cryostats operate in accordance with the same principle as regular thermoses but the requirements for heat insulation in them are much higher. Additionally, the outer wall of the vessel is cooled with liquid nitrogen.

The creation of such devices is accompanied by several technical difficulties, especially if the superconductors placed in them possess large dimensions. Under ground conditions such difficulties are fully surmountable, but in space flight they increase.

First, two small superconducting devices with a field of about 15,000 Oe cooled by helium in a supercritical state, i.e., at a temperature above its boiling point and increased pressure, were

installed on the "Cosmos-140" artificial satellite. The current in the casing of the solenoids was turned on on the ground prior to the launching of the satellite. Both devices successfully withstood the active section of the trajectory. The magnetic field in them existed for about 10 hours. The cause of the "breakdown" of the field was the rapid heating of the system with the creation of an artificial force of gravity as a result of the satellite's rotation. The experiment provided the opportunity to obtain interesting information and permitted drawing important conclusions for subsequent use of superconducting devices in space flights.

On satellite "Cosmos-213" investigations were already conducted with a considerably more complex device. It consisted of two solenoids disposed coaxially so that there was a gap between them with a magnetic field of about 1.5 meters. The intensity of the field reached approximately 20,000 Oe. Such a field can already be used for an analysis of the composition of the primary cosmic rays, in particular, to separate the electrons and positrons from their deviation in a magnetic field. A cryostat of special design permitted using a two-phase system at the start of the flight which contained both liquid as well as gaseous helium.

Experience confirmed the possibility of storing low-helium temperatures under conditions of space flight and, consequently, the employment of various superconducting systems on board spacecraft.

Further improvement of cryogenic techniques and, in particular, the development of shielded vacuum cryostats as well as new superconducting materials, will permit constructing in the immediate future magnetic systems of large volumes with an intensity of up to 100,000 Oe. Intended for operation under conditions of space flight, undoubtedly they will become a powerful tool for scientific investigations.

New prospects in the study of cosmic rays in the remote regions of the universe are being opened up by gamma-astronomy which was conceived comparatively recently. If we speak of gamma rays with energies greater than 50 MeV, they can be generated only by cosmic

rays. Therefore, measurement of the intensity and spectral and spatial distribution of such gamma rays may provide indispensible information on cosmic rays, especially if we consider that gamma radiation is propagated in a straight line and practically without losses over tremendous distances right up to the photometric radius of the universe.

The first test_ in the measurement of a global flow of gamma rays with energy greater than 50 MeV on artificial earth satellites were conducted using space stations "Proton-1" and "Proton-2." The information obtained permitted providing an upper limit for the flow of gamma quanta.

These investigations were then continued with the use of a more improved apparatus on satellites of the "Cosmos" series, in particular on "Cosmos-208." As a result, we succeeded in reducing the upper limit of the global flow of gamma quanta by approximately four times.

INVESTIGATION OF ANNIHILATED GAMMA RADIATION

In 1928, P. Dirak pointed for the first time to the existence of a special symmetry in nature. It consisted of the fact that for each particle of matter there exists a sort of "twin" - an antiparticle which has the same mass and internal moment of quantity of movement but possesses the opposite sign of electric charge.

In 1932, P. Dirak's hypothesis received confirmation. Positrons were discovered in cosmic rays, i.e., anti-electrons - the first antiparticle. And 20 years later, antiprotons, antineutrons, and antihyperons were discovered on accelerators. Moreover, theory confirms that along with the elementary particles component particles should exist - antinuclei consisting of antiprotons and antineutrons and, consequently, atoms of anti-elements in which there will be a positron instread of an electron. Such a high degree of symmetry of the laws of nature with respect to particles and antiparticles permits assuming that it extends to the entire universe. In other words, particles may exist in the universe which consists of

antimatter. True, up to now no experimental or observation data exist which would confirm or refute with any specificity the presence of the indicated symmetry.

In considering the symmetry of the universe, the question of the scale of division of matter and antimatter arises. Are the stars and antistars presented equally in the galaxies, or is every other galaxy antimatter, or is the scale of division something else?

In 1960, Academician B. P. Konstantinov proposed the hypothesis of a possible exchange between stellar systems of matter and antimatter by macroscopic bodies of the asteroid or meteor type. An asteroid, landing in the solar system, should behave substantially different in comparison with regular asteroids. Possibly, just such bodies of antimatter are comets, the behavior of which differs sharply from the behavior of other heavenly bodies. And since the observable meteor showers are formed as a result of the disintegration of comets, they should consist of small meteor antibodies.

One of the possible ways of checking the hypothesis of the antimatter nature of meteor showers may be the observation of integral flows of annihilation emissions which should arise in the upper layers of the earth's atmosphere with the "burning" of antimeteors. In the "burning" of an antimeteor, for the annihilation of one antinucleon there will be 1.5-2 gamma quanta with an energy of 0.511 MeV which may emerge from the atmosphere and be observed in the orbit of an artificial earth satellite.

Since the departure of energy per unit of mass of an antimeteor is considerably higher that for a regular meteor, it should be assumed that the mass of the antimeteor should be very small. Experimental estimates determine it with a value on the order of 10^{-9}-10^{-10} g. The overall mass of antimatter introduced into the earth's atmosphere by a stream of antimeteors in a day is 0.01-1 g. Annihilation of such a quantity of antimatter creates an average flow of gamma quanta on the orbit of the earth satellite with an energy of 0.511 MeV, which equals 0.03-3 $cm^{-2} \cdot sec^{-1}$.

Observations of the intensity of annihilated gamma radiation with an energy of 0.511 MeV were conducted on the "Cosmos-135" satellite during the period of action of the annual meteor showers of Geminids, Ursids, and Quadrantis in the winter of 1966-67. Measured were the intensity of the line of 0.511 MeV, the intensity of gamma radiation in a broad energy interval from 0.3 to 2.7 MeV, and the intensity of electrons with an energy greater than 1.5 MeV and protons with an energy greater than 27 MeV.

Measurements were conducted with the use of a scintillation gamma spectrometer with a 64-channel amplitude analyzer. The remote detector of gamma rays possessed practically isotropic sensitivity. Measurements of the gamma spectrums were conducted periodically once every 10 minutes. The time for the collection of information was two minutes. The intensity of the gamma radiation was determined from the data of each separate measurement. The counting of the gamma quanta and the counting of the charged particles were conducted every two minutes. With large loads, the time for filling the capacity of the accumulators of the recorders was measured instead of counting the pulses.

In processing the obtained information, first to be considered was the relative intensity of the annihilation[1] line in the spectrum of gamma rays. Since its share depends poorly on the geomagnetic latitude, the summing of the results of individual measurements accomplished at various latitudes was permitted. Determination of the average relative intensity of the line of 0.511 MeV in the spectrum of gamma rays, thus, was conducted with higher accuracy than in the case of a single measurement.

Depending on the results, all observations were divided into three periods for time: 13-18 December, 19-25 December 1966; 2-12 January, and several days in February 1967. The intensity of

[1]Translator's note: The Russian word used here is antigilyatsionnaya which does not exist in available sources and is probably a typographic error.

the flows of annihilation radiation from observations in the first period turned out to be approximately 1.5 times higher than in the second and almost twice as high as in the third period. In this, the higher value of annihilation radiation for the measurements of 19-25 December in comparison with data for January was determined primarily by the intensity of the 0.511 MeV line observed on 22 December.

In contrast to the time course of the intensity of gamma radiation in the line of 0.511 MeV, the flows of gamma rays in the continuous spectrum and the intensity of the charged particles underwent no substantial time variations.

Thus, in the experiment on "Cosmos-135" the time course of the intensity of electron-positron annihilation radiation was observed. The effect was approximately 50 percent.

Comparison of the results of measurements with data on the solar and geomagnetic activity and cosmic rays in the period of observations showed that the periods from 10 through 20 December 1966 and from 1 through 15 January 1967, which differ sharply from each other in the observed intensity of gamma quanta with an energy of 0.511 MeV, are very similar in solar and geomagnetic activity. Therefore, we cannot speak about some direct interconnection of the observed effect and solar activity. Evidence in favor of this is the fact that the increased intensity of the annihilation line in the spectrum of the gamma rays was observed equally day as well as night at all geomagnetic latitudes.

If we turn to the distribution of meteor activity in these periods, it turns out that the increase in the intensity of the annihilation radiation is observed namely during the action of the Geminids and Ursids meteor streams. In this regard, the maximum for the Ursids stream occurs just on 22 December when the greatest intensity of the line of 0.511 MeV was observed for the second period.

Thus, if we proceed on the assumption of the antimatter nature of the meteors, the observed effect can be explained by the flow of

antimatter introduced into the earth's atmosphere. The magnitude of the observed effect estimates it as approximately 20 mg per day.

TECHNICAL EXPERIMENTS

Further development of space investigations and, first of all, with the use of long-range apparatuses requires the creation of radio systems capable of providing dependable communication over any distances from the earth to the interplanetary station. This problem can be solved in two ways. Either by the creation of powerful antenna systems at ground points or by a substantial increase in the stability of the frequency and, consequently, by a narrowing of the emission band of the on-board master oscillators of electromagnetic oscillations.

The crystal oscillators which have been used up to now have a comparatively low stability. Moreover, they are subject to aging which causes drift and a considerable frequency shift. In comparison with them, maser oscillators are not distinguished by great power but their stability exceeds considerably the stability of the best crystal oscillators, thanks to which the stability of the receiver is increased many-fold.

The use of maser oscillators in the on-board equipment of the artificial earth satellites will permit not only accomplishing their control and the transmission of telemetry information over very great distances from the earth but also raising considerably the precision of operation of the time-programmed devices and the systems for the determination of the satellite's trajectory of movement.

Quantum generators using ammonia are most suitable for use as a highly stable on-board frequency generator. They are stable to vibrations, compact, and durable. It was such generators, operating on two opposing beams of molecules, which were installed on a number of "Cosmos" satellites.

A modification of a standardized satellite with solar batteries was used for the conduct of the experiments. A maser oscillator was installed on the outer surface of the satellite body. From above it was closed by a housing with double walls having openings whose area assured the necessary rate of removal of the ammonium into outer space. The openings on the two walls were displaced with respect to each other in such a way as to prevent the direct landing of cosmic particles and the sun's radiation in the maser oscillator. At the same time, the housing served as the base for the placement of receiver and transmitter antennas.

The electrical connection of the maser oscillator with the power supply sources which service the equipment as well as with the instruments of the scientific equipment located inside the body was accomplished through hermetic plug connections installed on special flanges.

The experiment on the satellite requires first of all the opportunity to measure the rated values of frequency stability in space flight. For this, it is necessary to accomplish its comparison with a standard ground frequency.

Used in the tests on the "Cosmoses" as a ground standard were three identical, independently operating maser oscillators having the same design and operating regime as the on-board oscillator. A change in the frequency of any of the ground oscillators could be precisely determined relative to the other two.

During transmission to a ground station, the frequency of the on-board oscillator will be biased considerably as a result of the Doppler effect. To eliminate this shortcoming, a method of automatic compensation for the Doppler effect with two-way radio communication between a ground station and the satellite was worked out and used sucessfully.

The oscillator operated stably at various altitudes above the earth, within and outside the radiation belt, with the satellite's illumination by the sun and in the earth's shadow. Thus, the

possibility for the operation of quantum frequency standards under conditions of a natural vacuum, weightlessness, and other factors of space flight was confirmed experimentally.

Fig. 6. Satellite with an electric-wheel orientation system ("Cosmos -23").

The data which were obtained permitted drawing conclusions necessary for the further design development of on-board maser oscillators for the creation of industrial models for broad application.

The automatic docking of two spacecraft in orbit was also accomplished for the first time using the "Cosmos" satellites. It was accomplished first on satellites "Cosmos-186" and "Cosmos-188" and then repeated successfully on satellites "Cosmos-212" and "Cosmos-213." The main goal of this work was a check of the scientific ideas and design decisions for the automatic docking of two spacecraft.

Automatic docking is the most important task of the development of space technology. It is known that the placing of only one kilogram of load into the orbit of an artificial satellite requires about 50 kg of initial weight of the launch vehicle. One can imagine the weight necessary at the launching of a rocket which is necessary to accomplish the flight of man to the planets of the solar system. It will number tens of thousands of tons. Such launch vehicles are unique designs which require complex stage-by-stage work under ground and flight conditions. Colossal launch structures are required

for their launching.

Docking can take place with the participation of man or completely automatically. Of course, participation of man would facilitate considerably the accomplishment of the assigned task but it would require the provision of conditions for his normal vital activity, flight safety, and return to earth. And this, in turn, would require either an increase in the weight of the spacecraft or a reduction in the payload.

To assure automatic search, closing and docking, special equipment was installed on each of the "Cosmoses" which participated in the docking: equipment of the system for orientation and automatic control of movement; power plant capable of repeated action to correct the orbit and for closing; low-thrust engines for orientation and docking; equipment to control the docking and docking units. On one of the satellites there was a docking unit of the active type - a rod, and on the other a unit of the passive type - a receiving cone.

Automatic docking was conducted in the following manner. After the orbiting of both satellites, mutual search is conducted with the use of a radio guidance system which provided the measurement of the parameters relative to the movement of the satellites - distance between them, rate of its change, angular velocity of the line of sight, etc., a straight line which connects the centers of mass of the satellites, angles between the lines of sight and the structural axes of the satellites.

With the closing of the satellites to a distance of about 300 meters, a closing-correction engine unit operates. Further closing is accomplished using the low-thrust system of engines. In this a low relative velocity of movement of the satellites is attained on meeting - on the order of 0.5-1 m/s and, thereby, docking safety.

"Cosmos-186" and "Cosmos-188" accomplished flight in a docked state for 3 hours 30 minutes, and "Cosmos-212" and "Cosmos-213 - for 3 hours 50 minutes. In this, a check of the on-board systems and the electrical circuits of the satellites was conducted. Then, on command from earth undocking was accomplished. After the undocking, the satellites continued flight according to the assigned program.

Unquestionably, the experiments on automatic docking which were accomplished successfully on the satellites of the "Cosmos" series open up broad prospects for the creation of complex space systems and, first of all, of multipurpose orbital stations.

* * *

Science is standing on the threshold of new discoveries and an even deeper penetration into the secrets of the outer space which surrounds us. We can foresee that Soviet scientists, armed with an advanced outlook and an outstanding base for investigations, will make a valuable contribution to the development of world science. Evidence of this is the ever newer launching, into space orbits, of Soviet ships of the "Soyus" series, "Venus" automatic interplanetary stations, and "Cosmos" satellites, and the results of the space experiments recently accomplished.